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Water Resources Support Center  
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# Examination of Noise Management Approaches in the United States

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**EXAMINATION OF NOISE MANAGEMENT  
APPROACHES IN THE UNITED STATES**

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## ABSTRACT

This report is intended to serve as a reference document on noise management approaches used in the United States. Emphasis has been placed on identifying and evaluating the full range of techniques and measures which are available when selecting a noise management strategy. Broadening the range of choice is a first step in moving toward the resolution and prevention of noise/land use conflicts. Awareness of the available options is of critical importance when individual actors in an issue have limited unilateral power to achieve objectives.

The first three chapters of the report provide the reader with background material designed to aid in the understanding of noise management issues. A brief description of the noise problem in the U.S. is given, followed by a discussion on conceptual approaches to noise/land use issues. Some basic concepts of sound and the measurement and assessment of noise are reviewed. In addition, the management application of noise descriptors, relating human responses to noise exposure levels, is examined. In Chapter III, a change is made from describing the noise environment, to describing the legal framework of statutory and case law that shapes management policy.

Chapters IV through VI are devoted to identifying and evaluating management approaches. A summarization of seven major federal noise management programs is presented. Differences in these programs can be described in terms of the type and intent of noise levels or standards used to determine management policy choices. The effect on land use management, of linking policies to noise levels, is that land can be classified into noise zones.

After reviewing major management programs, specific management techniques and measures are identified and evaluated. This lengthy assessment is structured according to the four major categories of available management options: physical techniques, organizational measures, public relations/interaction measures, and administrative techniques. While local land use management is an administrative solution to noise/land use issues, the available techniques are examined in detail in a separate chapter. As with many of the available techniques, the effectiveness of land use management is greatly increased when introduced as a preventive measure.

Management approaches such as the Air Installation Compatible Use Zone (AICUZ), Installation Compatible Use Zone (ICUZ), and Federal Aviation Regulation (FAR) Part 150 programs emerge as the most likely mechanisms for achieving noise compatible land use. The probability of success is increased when rigorous noise control efforts are coupled with an ongoing process of interaction with local communities.



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# **I. INTRODUCTION**

## **PURPOSE**

The primary purpose of this report is to aid in the development of a noise management program (NMP) for U.S. Army Europe (USAREUR) in Germany. The focus of this particular report, however, is not on noise management in Europe and not solely limited to military noise management. The goal is to provide a reference document of noise management approaches used in the United States. It is believed that identifying, describing, and evaluating management efforts in the U.S. will help to ensure that a comprehensive and rigorous management approach is developed for USAREUR.

Specific objectives of the research include:

- Identifying common management strategies or approaches to noise/land use issues
- Identifying and evaluating the effectiveness of specific management measures and techniques
- Identifying "lessons learned" from past noise management experiences in the U.S.

Specific noise sources focused on in the research include jet aircraft, fixed-wing aircraft, and rotary-wing aircraft, impulse noise from heavy weapons and explosions, vehicles, small arms, and fixed facilities. In addition, it should be noted that emphasis is placed on examining environmental as opposed to occupational or workplace noise.

## **METHODOLOGY**

The methodology for developing this report was composed of two basic parts: (1) a set of open-ended interviews with noise experts and program managers and (2) a review and synthesis of pertinent literature on noise management.

A total of 25 interviews were conducted over a one-and-a-half-month period from mid-May to mid-June 1988. Twenty-two of the interviews were conducted over the phone, and the remaining three were done through the mail. The list of individuals interviewed and the interview questions asked are given in Appendix A.

The objectives of the interviews were to identify current issues and to obtain up-to-date information on noise management. A large number of invaluable sources of information were either referenced in the interviews or obtained later directly from the

interviewees. While the interview process was not designed to be an original piece of research, many insights were gained from the interviewees and, where appropriate, have been incorporated into this report.

## STRUCTURE OF THE REPORT

A 1977 National Research Council report to the Environmental Protection Agency is prefaced by the remark that "no report on noise can be truly complete; the topic is too vast for a single volume" (NRC, 1977). Given the broad objective of this present report, it should be recognized that no part of the discussion on noise management should be taken as an exhaustive review. Selected areas have been targeted for emphasis. The annotated bibliography contained in Appendix B provides a review of the literature on noise management and should be useful to the reader as a guide to sources of additional information on specific research questions. The following is an introductory summarization of each chapter in the report.

Chapter I introduces the purposes and methodology of the report. A brief description of the noise problem in the U.S. is given, followed by a discussion on conceptual approaches to noise/land use issues.

Chapter II examines some basic concepts of sound and the measurement and assessment of noise. The management use of noise descriptors is analyzed.

Chapter III provides an overview of the legal framework for noise management. A listing and description of prominent federal legislation are given. Selected pieces of pertinent case law are discussed.

Chapter IV describes the form and function of major noise management programs in the U.S., focusing on the use of noise levels and noise zones.

Chapter V identifies and assesses the individual measures and techniques that can be used in developing a noise management strategy. Specific measures and techniques are categorized and discussed within four major groups: physical techniques, organizational measures, public relations/interactive measures, and administrative techniques.

Chapter VI examines in greater detail administrative techniques for local land use management. A summary outline identifying and evaluating available techniques is included.

Chapter VII summarizes and discusses the major noise management lessons covered in the report.



## CLARIFICATION OF TERMS

The following definitions of some commonly used terms are to clarify their meaning and usage within this report.

Noise abatement will be used to refer to an actual reduction in the noise emitted by the source. Noise mitigation is a broader concept which refers to the reduction of the noise impact. Noise abatement can be thought of as a subset of noise mitigation. Mitigation will also be used in this report to refer to any techniques which attempt to influence attitudes toward or perceptions of the noise by receivers.

The three basic elements of noise mitigation as defined by Raspet (1979) include:

- (1) The source can be quieted.
- (2) The path over which the sound travels can be interrupted.
- (3) The receiver can be protected from noise.

Source, path, and receiver always provide the most useful framework for discussing noise mitigation techniques.

Noise management refers to the larger system or program for measuring noise levels and human reaction; determining current and future noise/land use issues; and identifying, assessing, and implementing mitigation techniques. A management strategy is the use of one or more mitigation techniques in an attempt to resolve or prevent a noise/land use conflict. Within this report, mitigation techniques will be categorized into four major groups: physical techniques, organizational measures, public relations/interaction measures, and administrative techniques.

## THE NOISE PROBLEM IN THE UNITED STATES

The objective of this section is to briefly examine the scale of the noise problem in the U.S. The first step is to identify the major sources of outdoor noise in urban settings. Elred (1983) identifies five: road traffic, aircraft, rail, industrial, and construction. Of these sources, road traffic is widely cited to be the most pervasive in terms of impact on population.

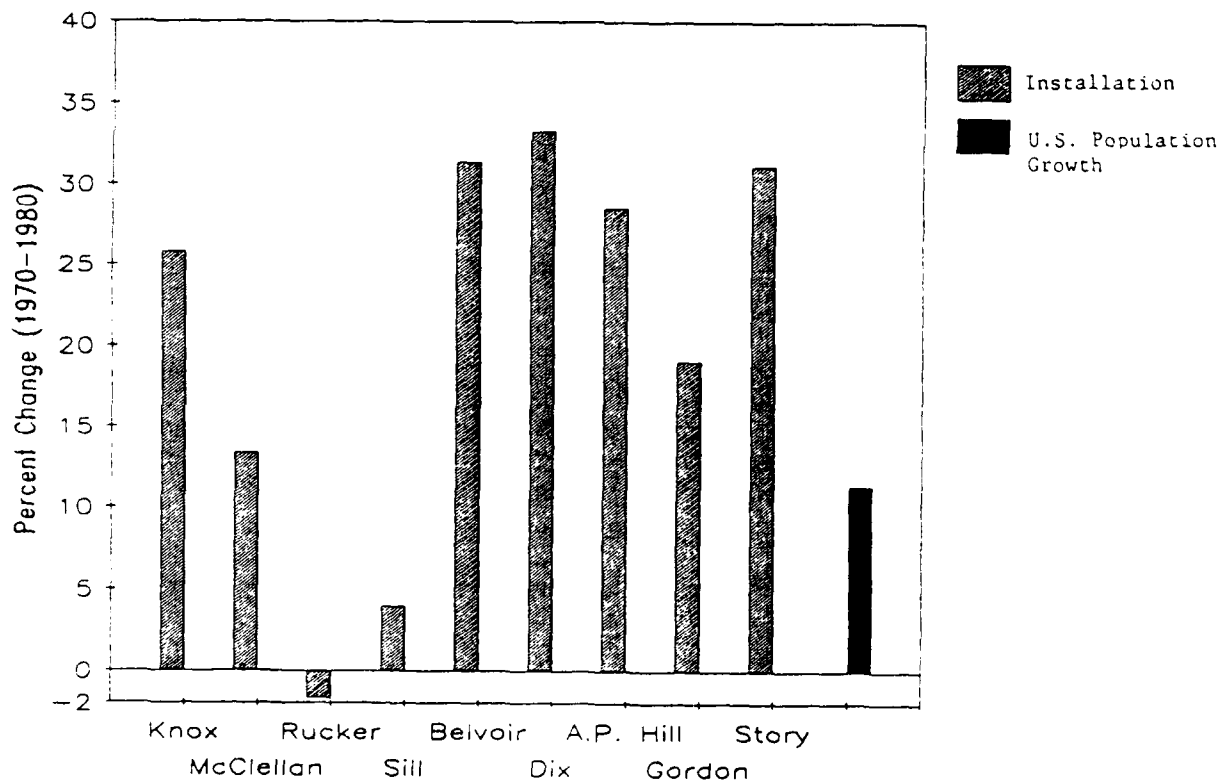
The following list shows the estimated 1980 U.S. population (in millions) living in urban areas exceeding an outdoor day-night sound exposure of 55  $L_{dn}$  for the five major noise sources (Elred, 1983).

Road traffic	96.8	Industrial	6.9
Aircraft	24.3	Construction	3.6
Rail	6.9		

The measurement of noise will be discussed in detail in Chapter II, at this point it should suffice to say that 55  $L_{dn}$  represents an average noise level roughly equivalent to light road traffic at curbside (Mulholland, 1985). It is also roughly the level where noise will begin to be considered an adverse component of the urban environment, although average community reaction can be expected to be only slight to moderate (Federal Interagency Committee on Urban Noise, 1980).

Aircraft noise around airports is less pervasive than road traffic, but it is a more intense and localized form of noise that has the potential to impose extreme impacts on entire communities (Mulholland, 1985). Military installations can be compared to airports as a potentially intense and localized noise source.

While for some sources, such as commercial aviation, the noise impact on total population has decreased within the last 10 to 15 years (Starley, 1988), for other sources it has not. This appears to be especially true in the case of the military. Figure I-1 compares growth in areas near U.S. Army Training and Doctrine Command (TRADOC) installations with that for all U.S. counties.



Source: TRADOC, n.d.

Figure I-1. Population Growth in Counties Adjoining TRADOC Installations with Noise Problems (1970-1980)

It can be seen that population growth around TRADOC installations encountering noise conflicts was greater than 20 percent between 1970 and 1980, as compared to approximately 11 percent for all U.S. counties (TRADOC, n.d.). In addition, military noise impacts are projected to increase in the future. As a general statement, noisier weapons and aircraft, more mobile noise sources capable of impacting a wider area, and encroaching urban growth all point toward the potential for increasing noise conflicts around installations.

## CONCEPTUAL APPROACHES TO NOISE/LAND USE ISSUES

Noise/land use issues can present some of the most difficult environmental problems to resolve. Often the most challenging aspect of noise management is selecting the appropriate conceptual approach to analyzing the problem. This section presents a discussion of some of the approaches available.

One approach is to view noise as an environmental pollutant and frame the problem in terms of transgressors and victims. Alternatively, the issue may be seen as one of conflict between competing interests, each asserting a legally or socially validated position. Finally, the idea of conflicting interests can be expanded on to recognize the often symbiotic relationship between noisemaker and noise receiver.

In a simple economic paradigm, noise is seen as an adverse externality imposed by the noise polluter on an unwanted party. The problem is one of forcing the noisemaker to "internalize" these costs or compensate the victim. Given that noise is often the by-product of some individually or socially desirable activity, complete reduction of the noise is usually not an acceptable or practicable alternative. In between the two polar extremes, complete reduction of the noise and absolutely no reduction or restriction, lies some socially optimum level. At this theoretical point, the marginal social costs of reduction will equal the marginal social benefits of reduction. The difficulty has always been in finding the optimum point.

The recognition that there is always a wide range of noise abatement or mitigation options available, each with differing associated costs and benefits, adds a layer of complexity to the analysis. It is not just choice of increasing or reducing the level of an activity and its concomitant level of noise. Choosing the socially optimum point means giving full consideration to the range of available management alternatives. Given that noise is a subjective environmental phenomenon, this list of options includes influencing attitudes and perceptions.

The problem with treating noise pollution as an externality is that the issue is often much more complicated than a simple two-party case of transgressors (polluters) and victims (Frankel 1986). An alternative perspective on noise/land use issues is to view them as conflicts between competing interests. While not necessarily mutually

exclusive, the activities or desires of the two sides in the issue will certainly affect each other. Both sides in the issue may have socially valid claims (i.e. national defense or interstate commerce versus quality of the environment). Kantor (1977) provides an example of this line of reasoning,

Both the "noise-generating" airport and the "silence-demanding" residences impose spillover effects on each other. It may be argued that, where two uses spill over on each other, neither has a constitutional right to prevail. The determination as to which use will prevail should be left to the legislature for resolution. Rationally, this determination will be made by comparing the relative costs and benefits of each solution.

The market provides us with a mechanism for making rational trade-offs between competing interests. However, adequately functioning markets do not exist for noise issues. The nature of the costs and benefits is often intangible. There can be numerous noise receivers, and possibly numerous noisemakers (as is the case with highway noise), and consequently, transaction costs will be high. In addition, legal uncertainty over property rights may further cloud the issue.

Given this conflict between competing interests and either the inadequacy or lack of a market to make allocative choices, noise/land use issues have the potential to ignite into legal and political battles. Both adversarial solutions (litigation) and political solutions (legislative change) are always options available in a conflict. Yet, both approaches have costs of their own, can be unpredictable, and often produce unsatisfactory results. One such possible result is to constrain future choices.

The current body of statutory and case law will serve to constrain the noise management options available in any particular situation. A further constraint on a noise management program may be the larger mission or directives of the responsible body. Prominent examples of this include the military mission to provide national defense or the Department of Transportation directive to protect the interstate commerce system. The situation of the military is unique, however, being both the noisemaker and the management or regulatory authority.

Within the context of public policy choices, benefit-cost analysis is one tool potentially available for aiding the decision-making process. An attempt is made at systematically evaluating alternatives, and determining the economically optimum choice. Alternatives are ranked according to the maximum net present value criterion. This ranking can then provide a valuable piece of evidence in the larger policy decision. A number of sources have encouraged the use of benefit-cost analysis in noise/land use issues. A useful overview of this approach is given in a 1977 report by the National Research Council of the National Academy of Sciences, Noise Abatement: Policy

Alternatives for Transportation. Cost-effective analysis, comparing the costs of alternatives which provide equal amounts of abatement, has also been used as a decision-making tool.

The primary method for attempting to assess nonmarket values (in particular noise abatement benefits) has been property value analysis in which the relationship between residential property values (or apartment rents) and noise levels is examined (NRC 1977). The belief is that environmental disamenities such as noise tend to be capitalized into property values. Properties burdened by noise are worth less than properties without. As a rough guide, it has recently been estimated that the value of the affected property will drop an average of 0.6 percent per decibel increase in noise (Frankel, 1986). This is consistent with a 1977 summary of studies (using post-1967 data) on the percentage reduction in average property values that was due to transportation noise. The summary showed a mean of .54 percent with a standard deviation of .24 for six studies of airport noise, and a mean of .62 percent with a standard deviation of .72 for three studies of highway noise (NRC, 1977). This "noise discount" can be seen as compensation to a property buyer for a future noise burden. In economic terms, compensation is the equivalent of the amount of noise abatement in which the individual is restored to his prepollution level of satisfaction. Against this backdrop of compensation, not all landowners and renters can be seen as victims. Former and current property owners who had their property value discounted are seen as victims. Individuals who purchase or rent property (with knowledge of the noise levels) at a discounted value, are seen as being effectively compensated for the future noise burden (Frankel 1986).

It must also be recognized that the elimination or removal of the noisemaker will not necessarily increase the value of surrounding properties. On the contrary, noise-generating facilities such as airports or military installations are often the focus of economic activities. As Frankel (1986) states "The income they generate, the employment opportunities they provide, and the transportation access they afford all help to support and enhance the property values of the nearby communities." This serves to illustrate that there may often be a "locational premium" associated with close access to a noisemaker. It is the interplay between both the "noise discount" and the "locational premium" that determines actual property values. This interplay and the difficulty of disentangling these two factors point to the often symbiotic relationship between noisemaker and local communities. A site which is burdened by noise (a negative technological externality) may also benefit economically from proximity to the noise source (a positive pecuniary externality).

In summary, the lack of functioning markets, the difficulty of applying economic analysis, the often dissatisfaction with adversarial solutions, and the many constraints on the actions of noise management programs all point to the tremendous difficulty in resolving noise/land use problems. An alternative approach is to involve all affected parties in an attempt to reduce the level of real or potential conflict.

This conceptual approach recognizes the often-functional interdependence of those involved in the noise/land use issue. It is not surprising that a variety of collaborative problem-solving and proactive-planning approaches have surfaced. The objective is to resolve a conflict before it becomes unmanageable (a full-blown legal or political controversy). A quote from a report (Engleman and Raspet, 1983) reviewing the Army's legal position in noise issues serves to illustrate this approach:

The best way for the Army to prevent litigation or the threat of a suit, is to avoid situations severe enough that the civilian community feels bound to seek restitution in the state or federal court system.

Programs that attempt to actively involve all affected parties and avoid or reduce conflict are now being implemented by both the Department of Defense and the Federal Aviation Administration.

Interactive management strategies based on the concept of reducing or preventing conflict may be particularly attractive from the perspective of the military. Increasing military noise has been matched against continued growth in adjacent communities. The need to preserve mission capability and the limited unilateral power to ensure local noise compatible land use may often require that some program of interaction with the community be implemented.

In the implementation of these programs, the insight to be gained from an economic perspective is that there are costs associated both with noise emissions and with noise mitigation. Neither a noise-free environment nor the unchecked growth of noise is likely to be an optimal social choice. Yet, between these two extremes there is tremendous "slack in the system" and due consideration should be given to the full range of alternatives for noise abatement and mitigation.

A primary objective of this report is to identify the full range of noise management techniques and assess general effectiveness and applicability. Unfortunately, past debate about noise management has been narrowly focused on technological or physical solutions. Caution should be taken in drawing any "across the board" conclusions about basic management strategies or programs. Site-specific analysis is always a requirement, and techniques such as benefit-cost analysis are not yet fully advanced to provide categorical conclusions about management programs (NRC, 1977). Problems such as separating the interaction effects of different measures used in combination prevent clear statements on the broad desirability of management strategies. Yet, caution should not mean paralysis and it is believed that the synthesis of information contained in the body of this report will lead to conclusions that can enhance management policy choices for USAREUR.

## II. THE ASSESSMENT OF NOISE AND COMMUNITY RESPONSE

In this chapter, some basic concepts of sound and the measurement and assessment of noise are reviewed. In addition, the management application of noise descriptors, relating human responses to noise exposure levels, is examined. The aim is to describe what noise is, how it is measured, and how those measurements are used by management.

Noise is often defined as unpleasant or unwanted sound. Based on this definition, noise is a subjective evaluation by each individual. The annoyance level of a particular sound will determine if it is unpleasant or unwanted. Frankel (1986) defines annoyance as:

A psychological response to a given noise exposure. It may result from speech or sleep interference, but it can arise in a variety of other circumstances. The perceived unpleasantness of the noise is a factor of annoyance, as is any anxiety or apprehension that the noise may cause.

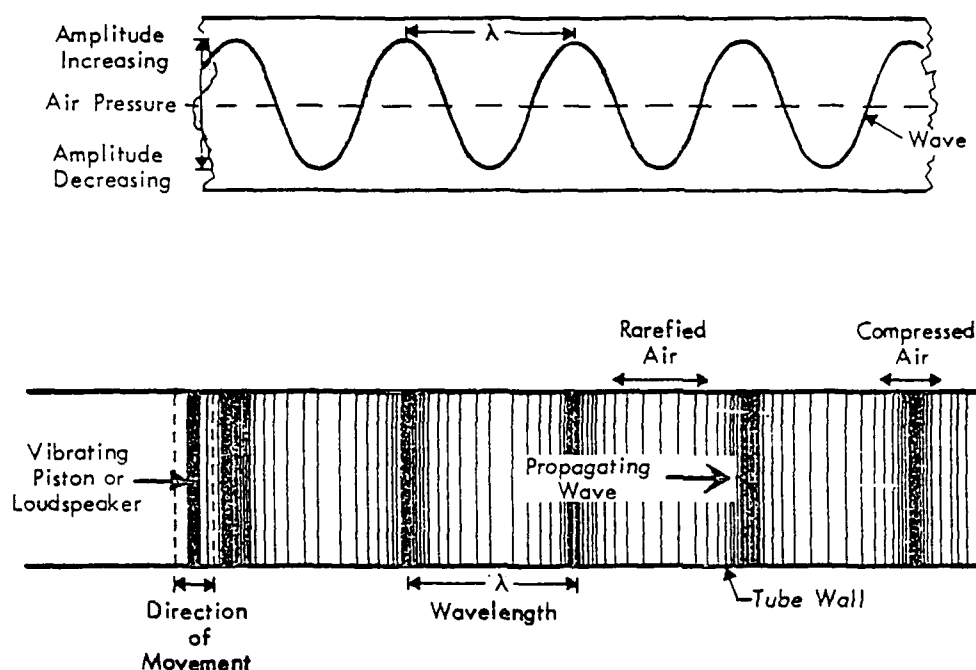
Excess noise can have several adverse effects on an individual. These effects include direct effects on the auditory system; indirect effects on other health, social, and economic variables such as productivity; and effects on the quality of life because of annoyance (NRC, 1977). In addition, physical damages to property such as the cracking of glass and plaster in homes from explosions and sonic booms can occur. Furthermore, a decrease in the value of property near a noise source can be a negative factor.

Noise does not have to be loud to annoy. The scraping of fingernails on a chalkboard is an example of an annoying sound to many individuals that is not necessarily loud. A loud noise may be pleasant to one individual and yet annoying to another. Since one person's noise is another person's music, a measure or index to account for the subjective differences is not possible. Instead, the intensity of the noisiness sufficient to annoy most people is the method used in developing noise measurements. (This will be discussed in more detail later in the chapter.)

### BASIC CONCEPTS OF SOUND

Before noise and noise indices (or noise metrics) can be understood, some basic concepts of sound must be discussed. Sound is any pressure variation in air, water, or other elastic medium caused by the vibration of an object. Normally, any atmospheric pressure variations must occur at least 20 times per second before they can be picked up by the ear (Bueche, 1965). An example of a noise vibration is the diaphragm on a

loudspeaker. As the diaphragm moves to the right, it compresses the air around it (compression), and as it pulls inward it creates an area of decreased air pressure, or a slight vacuum. This air is said to be rarefied and the disturbance is called a rarefaction. The distance between successive compressions or rarefactions is known as the wavelength of the sound wave. Figure II-1 is a graphical depiction of these concepts for a compressional wave in a tube.



Source: FHWA, 1980b.

Figure II-1. Depiction of Compressions and Rarefactions of a Sound Wave Generated in the Tube

The ability to hear a sound is dependent on the intensity of the sound pressure as well as the frequency of the sound. Frequency is the number of pressure variations or compressions and rarefactions per unit of time. It is measured in cycles per second, known as Hertz (Hz). Sound consisting of a single frequency is known as a pure tone (Bruel and Kjaer, 1984b). Most sound is a complex combination of several different frequencies.

The relationship between wavelength and frequency is expressed as

$$\lambda = \frac{v}{f}$$



where

$\lambda$  (lambda) = wavelength in feet or meters

$v$  = speed of sound in feet or meters per second,

344 meters per second at room temperature

$f$  = frequency in Hertz, cycles per second

## Decibels

The human ear can detect a tremendous range of sound pressures. An amplitude of 20 millionths of a pascal, 20 micropascals, can be detected by the human ear. This equivalent to a soft whisper is five billion times less than normal atmospheric pressure. The ear can tolerate pressures more than a million times higher than this level (Bruehl and Kjar, 1984b). This incredible range of sound pressures is analogous to the difference between one inch and 1,575 miles (FAA, 1983).

Because of this large range of pressure levels, a linear scale of measurement is rather unmanageable. The logarithmic scale more closely resembles the response of the ear to sound. The unit used to measure sound is called a decibel. A decibel is not an absolute unit of measurement but a ratio between the sound of interest and the threshold of hearing at 20 micropascals. The decibel scale compresses the range of a million pascals into a more manageable range of 120 decibels (Bueche, 1965). The formula for determining the decibel level of a sound is expressed in sound pressure levels (SPL) and is expressed mathematically as

$$\text{SPL} = 10 \log \left( \frac{p^2}{p_o} \right)$$

where

$p$  = sound pressure of acoustic signal above atmospheric pressure

$p_o$  = reference pressure of 20 micropascals

Since decibels are logarithmic, they cannot be added arithmetically. Two noise sources each 40 dB in sound level do not equal 80 dB, but 43 dB when combined. Simplified decibel addition is discussed in Planning in the Noise Environment (DOD, 1978).

## Effects of Frequency

Although a sound may have a high level of intensity, this does not guarantee that it will be heard. The normal ear can hear sound in a frequency range of 20 to 15,000 Hz (Bueche, 1965). The ear is most sensitive in the 3,000 Hz frequency. At other frequencies, the intensity or the sound pressure level (SPL) must be much higher to be audible. At the threshold of pain, approximately 120 dB, frequency has little effect. The effects of frequency are actually somewhat complex, since most sounds are not composed of a single frequency but multiple components (DOD, 1978).

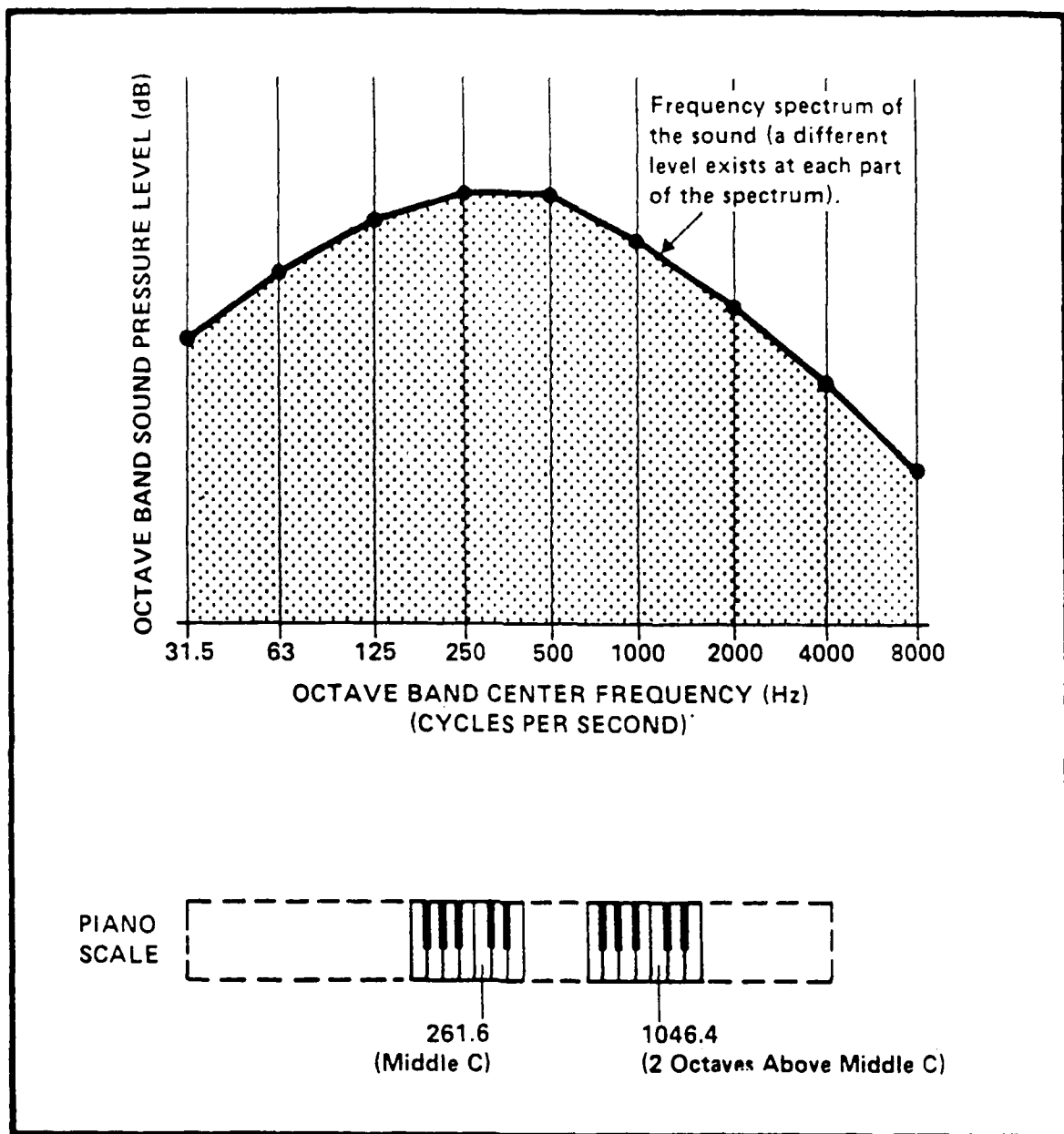
When detailed information about a complex sound is required, the frequency range between 20 to 20,000 Hz is divided into bands called octaves. An octave is a band where the highest frequency is twice that of the lowest (Brueel and Kjaer, 1984b). Filters which only allow sound within a specific band are used to analyze the sound. The dividing of a complex sound is termed frequency analysis and the results are presented as a spectrogram. A spectrogram for jet exhaust noise is presented in Figure II-2.

The knowledge of the frequency spectrum of a noise signal is important, since people have different hearing sensitivities and react differently to various frequencies. In addition, most engineering solutions for reducing or controlling noise are frequency dependent (DOD, 1978).

## Distance

Whenever sound waves are emitted, they are spread out uniformly in all directions, similar to ripples on a pond, as the sound waves travel farther from the source. For sound in air, a doubling in distance results in a six dB drop in the sound level (Brueel and Kjaer, 1984b). By reflecting the sound, the distance it travels will increase and sound attenuation will occur. Since sound is a low form of energy, it can also be absorbed by material where it is released as heat energy. Most methods of sound attenuation use materials that both absorb and reflect the sound waves. What is not absorbed or reflected will be transmitted through the material (Mulholland, 1985).

In addition, atmospheric effects can attenuate sound waves. Molecular absorption accounts for the absorption of certain high-frequency energy over relatively long distances. Air temperature and relative humidity are the main factors for this effect. Furthermore, wind and temperature gradients affect the propagation of sound, as does terrain, which reflects and absorbs sound waves (DOD, 1978).



Source: DOD, 1978.

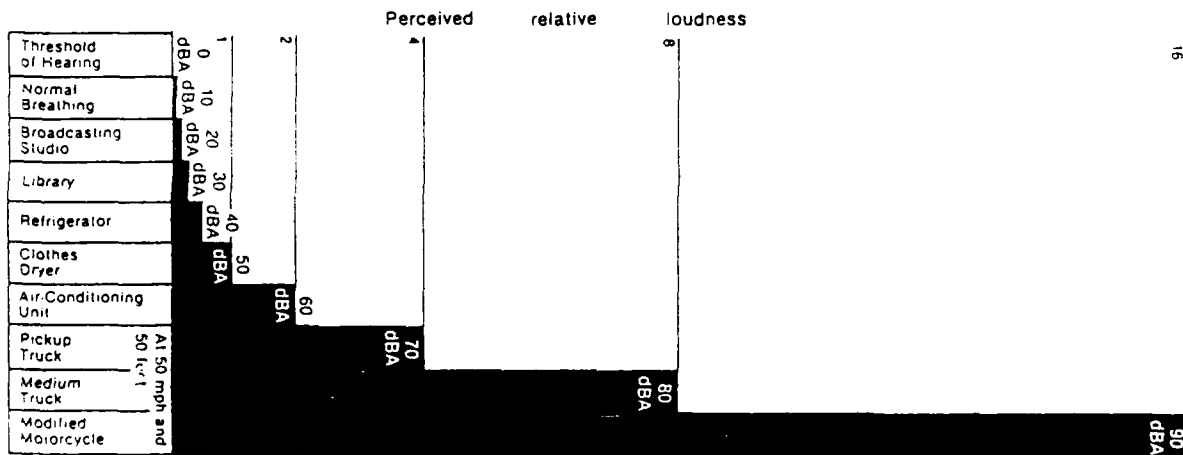
Figure II-2. Typical Frequency Spectrum of Jet Exhaust Noise

## NOISE INDICES

An incredible array of different measures are used to assess human exposure to noise. It is because of the many different characteristics of noise, such as intensity, duration, frequency, and intermittency, that numerous noise indices exist. Each index is designed to satisfy different requirements or to emphasize certain sound characteristics. For example, a measure to account for the low frequency and short duration of blast noise may not be appropriate to evaluate the high-frequency continuous nature of a turbine whine.

Commonly, weighting functions are applied to each frequency in the spectrum to account for the differential sensitivity of the human ear. The A-weighted sound level is a measure which deemphasizes low-frequency sound, as does the ear. A measure based on the subjective assessment of the relative noise level is the perceived noise level (PNL). This subjective assessment is based on the noisiness (the annoying quality) of the various frequency components rather than loudness. Increased emphasis is placed on the upper portion of the spectrum, 2,000–4,000 Hz (DOD, 1978).

Figure II-3 illustrates the A-weighted decibel scale for various noise sources and the associated perceived relative loudness. Based on tests of the perceived loudness of various noise levels, 70 dBA is perceived to be twice as loud as 60 dBA (FHWA, 1980). The sound energy of a noise source actually doubles from 60 to 63 dBA.

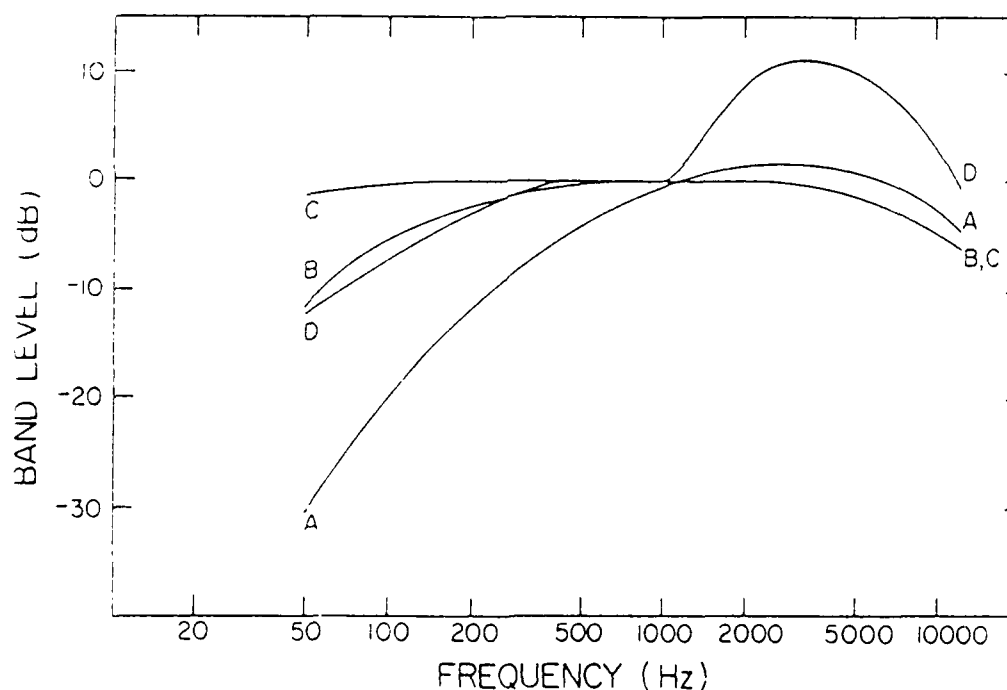


Source: FHWA, 1980f.

Figure II-3. The A-Weighted Decibel Scale and the Perceived Relative Loudness from Various Sources

A measure also widely used, particularly for large amplitude impulse sounds such as sonic booms, explosions, and weapons noise, is the C-weighted sound level. The C-weighted network will reflect both loudness and low-frequency vibrational energy (Luz, Raspet and Schomer, 1985). This weighted measure provides little adjustment to the noise signal over the audible frequency range and therefore may not correlate well with subjective tests (although as discussed later in this chapter the C-weighted network can be used to predict annoyance levels for impulse noise). The development of the measure was based on experiments using pure tones. Most common sounds are not pure tones but complex signals of several different frequencies (Brueel and Kjaer, 1984b).

Two additional weights, B and D, are also sometimes used for measurement. However, most of the management programs in this report utilize either the C- or A-weighted sound levels. Therefore, only these weighting measures will be covered. All four frequency weighting measures are illustrated in Figure II-4.



Source: NRC, 1977.

Figure II-4. Frequency Weightings Used in the Direct Measurement of Sound

Most of the indices can usually be related to each other by considering specific correction factors. The main reason for the disparity is due to the emphasis on particular characteristics of the noise source that the index is intended to measure. The following section will briefly discuss several noise indices, the correction factors that vary between indices, and the relationship between each. The descriptions of the various indices are based on several sources, predominantly FHWA, (1980), DOD (1978), and NRC (1977).

### **A-Weighted Measures**

A-weighted measures are commonly used in the U.S. for the measurement of community and transportation noise. The Department of Transportation and the Department of Defense currently use A-weighted noise descriptors to measure noise impacts on communities. Following are a list and short description of the more common A-weighted measures.

#### **Sound Exposure Level (SEL) ( $L_{AE}$ )**

The sound exposure level is the level of sound accumulated during a given period of time or event. SEL can be defined as "the constant level acting for one second which has the same amount of acoustic energy as the original sound" (Bruel and Kjaer, 1984b). SEL is appropriate for a discrete event, such as the passage of an airplane or automobile. This measure is not an average but a kind of sum. This will account for any fluctuations in sound levels for an event that would not be recorded using an average value. Steady sounds will have an average value similar to SEL. If the SEL is based on a A-weighted network, then it is symbolized as  $L_{AE}$ .

#### **Equivalent Sound Level (EQL) ( $L_{eq}$ )**

This sound level is an average (on an energy basis) of the A-weighted sound levels over a period of time.  $L_{eq}$  provides the equivalent level of continuous noise for a specific time period with fluctuating noise sources (DOD, 1978). The time period under consideration is dependent on the situation. Eight hours would be appropriate for determining the exposure to a worker, while in other instances, one hour or 24 hours may be suitable. SEL can be correlated to  $L_{eq}$  for noncontinuous operations by summing on an energy basis the SEL values and dividing by the appropriate time period.

**$L_{10}$** 

This descriptor is used as an alternative to  $L_{eq}$  by the Federal Highway Administration (FHWA) but will apply to any noise source.  $L_{10}$  is defined as the sound level that is exceeded 10 percent of the time for the period under consideration. Under typical conditions,  $L_{eq}$  approximately equals  $L_{10}$  minus three decibels (Federal Interagency Committee on Urban Noise, 1980).

**Day-Night Sound Level (DNL) ( $L_{dn}$ )**

The day-night sound level is applicable to all sources and is widely used in the U.S.  $L_{dn}$  is the 24-hour average sound in decibels for the period from midnight to midnight, with a 10 decibel penalty added to sound levels occurring from 10 P.M. to 7 A.M. The only difference between  $L_{dn}$  and  $L_{eq}$  for 24 hours is the nighttime penalty.

**Community Noise Equivalent Level (CNEL)**

The CNEL, developed for the state of California, is nearly identical to DNL except for the addition of an intermediate weighting of five decibels in the early evening hours between 7 P.M. and 10 P.M. DNL is approximately equal to CNEL in almost all situations.

**C-Weighted Measures**

C-weighted noise measures are used in place of A-weighted measures to account for the additional annoyance of structural vibration from impulse noise. The C-weighted sound exposure level ( $SEL_c$ ), C-weighted day-night average sound level ( $L_{c, dn}$ ), and the C-weighted equivalent sound level  $L_{ceq}$  are all equivalent to their A-weighted counterparts except that C-weighting is substituted for the A-weighting.

**Measures Based on the Perceived Noise Level**

The perceived noise level (PNL) is based on the subjective assessment of the relative noisiness of the different frequency components of the noise signal. Similar to the A-weighted measure, weights are given to each component. The following are measured based on PNL.

### **Tone-Corrected Perceived Noise Level (PNLT)**

The adjustment for pure tones of strong discrete frequency components to which humans are sensitive is the adjustment the PNLT makes to the PNL measure. Pure tones are those which consist of a single frequency. At specific frequencies, individuals experience a high level of annoyance.

### **Effective Perceived Noise Level (EPNL)**

This measure is found by integrating the PNLT over the period of a single event. In addition to a pure tone adjustment, frequency and duration are considered. The measure is often used for aircraft flyovers.

### **Composite Noise Rating (CNR)**

The composite noise rating was, at one time, widely used by airports as a measure of the 24-hour noise environment around military and civilian airfields. CNR is determined by overlaying three zones of perceived noise level (PNL) contours based on flight paths and aircraft types. Five decibel adjustments are made in the PNL contours to account for the number of flights occurring on typically busy days. To incorporate community reactions to run-up operations, a 20 dB penalty is applied to the affected contours (DOD, 1978). CNR-35 dB is approximately equal to  $L_{dn}$ .

### **Noise Exposure Forecast (NEF)**

NEF was developed as a refinement to CNR. It is not a measurable quantity (Magan, 1979). NEF is based on EPNL rather than PNL as is the composite noise rating. This allows NEF to account for such factors as the duration of aircraft flyovers and discrete (pure) tones such as turbine "whine" not covered by CNR. NEF + 35 is approximately equal to  $L_{dn}$ .

## **CORRECTION FACTORS**

All of the previous noise indices are designed to consider specific characteristics of the noise environment. Each has one or more correction factors included to account for potential impacts. The National Research Council (1977) lists nine correction factors used in the various indices. These include:

- (1) Duration -- the length of time during which the sound is emitted.



- (2) Frequency of occurrence -- a correction that indicates the number of noise events that occurs in a specified length of time, such as the number of aircraft flyovers during a 24-hour period.
- (3) Discrete frequency components -- a correction for the presence of audible pure tone components in noise.
- (4) Impulse noise -- a correction for noise that is composed of discrete impulses, such as noise produced by an air hammer.
- (5) Background noise -- the average noise level when the source is not operating. Some measures of noise magnitude such as  $L_{eq}$  or SEL automatically reflect the background sound level. Some indices require one explicit calculation of the background level with the source removed.
- (6) Variability -- a measure of how much the noise fluctuates over a given time period.
- (7) Time of day -- a correction for the time of day in which noise occurs. Typically, indices impose a penalty for nighttime as opposed to daytime occurrences.
- (8) Time of year -- a correction for the season in which the noise occurs. An index may impose a penalty for a summer exposure as opposed to a winter exposure because building windows are left open in the summer.
- (9) Previous exposure of the community to noise -- a correction that assumes that communities with previous exposure to noise levels that approximate the new noise level will be less likely to protest the added noise, provided that the total noise level is below some maximum level.

Table II-1 indicates which of these correction factors are accounted for in the noise indices mentioned previously. They are broken down by A-weighted, C-weighted, and perceived noise-level-based indices and further subdivided by their applicability for use in single or multiple events. The selection of a noise index should depend on the sensitivity of the noise environment to these correction factors. It is quite possible that the use of two or more noise metrics will be needed to accurately describe the noise environment.

## PREDICTION AND MONITORING

Noise exposure levels can be either predicted or directly measured. A variety of computer models are available for predicting noise levels. Continuous monitoring systems are also being used in some cases for on-site measurement. There are two basic kinds of monitoring: "monitoring to verify a computer-generated contour and online monitoring to detect high noise levels in a noise sensitive community," (Luz, 1988).

Some noise metrics, such as the DNL, are physically measurable quantities that can be either predicted or measured with portable monitoring equipment (Magan, 1979). Other metrics, such as the noise exposure forecast (NEF), are calculated values

TABLE II-1  
CORRECTION FACTORS USED IN NOISE METRICS

	Abbr- viation	Symbol	Duration	Frequency of Occurrence	Pure Tones	Impulse	Back- ground	Vari- ability	Day Night	Seasonal	Previous Experience
Based on A level											
Single event Sound exposure level	SEL	$L_{Ae}$	X								
Multiple events	CNEL	-	X	X					X		
Community noise equivalent level	DNL	$L_{dn}$	X						X		
Day-night average sound level	EQL	$L_{eq}$	X								
Equivalent sound level $L_{10}$	$L_{10}$	$L_{10}$	X								
Traffic noise index	TNI							X			
Based on C level											
Single event C-weighted sound exposure level	$SEL_c$	$L_{Cae}$	X			X					
Multiple events	$DNL_c$	$L_{Cae}$	X			X					
C-weighted day-night average sound level	$EQL_c$	$L_{Ceq}$	X			X					
Based on perceived noise level											
Single event Effective perceived noise level	EPNL	-	X		X						
Tone-corrected perceived noise level	PNLT	-			X						
Multiple events	CNR	-		X		X	X		X	X	X
Composite noise rating	NEF	-	X	X	X				X		
Noise exposure forecast											

Source: adapted from NRC, 1977.

that cannot be directly measured. The calculation of exposure levels is often a complex procedure that can be greatly simplified through the use of a computer model. Predicted exposure levels can then be easily presented on a map as noise contours.

The Federal Aviation Administration's (FAA) Integrated Noise Model (INM) is the standard predictive model for airport noise exposure (FAA, 1983). Updated versions of the INM are released periodically. The input for the model includes aircraft noise and performance information, activity levels, operational data, and a number of other variables such as airport evaluation, wind conditions, and average temperature (FAA, 1983). A variety of other models are available. For example, the U.S. Air Force has developed a noise map model (NOISEMAP, VERSION 6) which is more sophisticated than the INM (Cox, 1988). The U.S. Army Construction Engineering Research Laboratory (CERL) has developed and updated a blast noise prediction model, BNOISE 3.2 (Schomer et al., 1981).

As Schomer, DeVor, and Neathammer (1984) note:

It is common practice to use computer-generated noise contours or noise zone maps to assess noise impact and perform noise related land-use planning. However, developers and other interested parties often question the accuracy of computer simulations and suggest direct measurement to "verify" the computer predictions.

The INM has generally been shown to be accurate within  $\pm$  three to  $\pm$  five dB (FAA, 1983). Roughly four to eight weeks of monitoring yearly can produce predicted noise exposure levels within  $\pm$  two to  $\pm$  three dB of the true DNL (Schomer et al., 1984).

The first permanent and continuous acoustical monitoring at a major U.S. airport was in 1967. By 1984, over 26 noise monitoring systems were in use (Bragdon, 1984). Monitoring is not always encouraged. It can be expensive and time-consuming, often resulting only in marginal increases in accuracy (Cox, 1988). Also, it does not appear to be possible to monitor blast noise, for computer-generated contour verification, even on a continuous basis (Schomer et al., 1984). However, it may still be valuable to monitor blast noise in order to detect for the potential of annoyance or complaints in a noise sensitive community. As Luz (1988) has noted, there are demonstrated cases of a 40 dB spread between best case and worst case predicted impact in a community from blast noise, the great variability being introduced by the weather. Where possible, a monitoring program can: provide objective data, aid in the assessment of regulatory compliance, assist in addressing noise impact issues, assist in official inquiries of noise events, and possibly instill public confidence in the effort to control noise (Bragdon, 1984).

The selection of a noise metric and a prediction or monitoring program for determining noise exposure levels is a key element in any noise management program. As will be discussed in the next section, it is the relationship between exposure level and expected community response that is often the basis for fundamental policy choices.

## **THE MANAGEMENT USE OF NOISE DESCRIPTORS**

### **Relating Sound Level and Human Response**

The most elementary use of a noise index or metric is the attempt to accurately reflect the multivariate characteristics of sound; the objective is to measure sound. A broader objective of noise management is to assess individual or community response to exposure at different sound levels. The management application of noise indices is really an attempt to describe the full "noise environment" which includes both sound levels and human responses. Hence the term descriptor, which is often used interchangeably with noise index and noise metric. Duffy (1986) has called a noise descriptor a "psycho-acoustic" bridge which attempts to connect the level of radiated sound energy with community reaction to it.

An accurate description of the noise environment allows standards or levels to be developed for directing noise management policies. The establishment of noise standards may be based on the health and annoyance levels of the general public. The subjective nature of annoyance by individuals will result in a small percentage of the population reporting a high degree of annoyance in relatively quiet settings and other portions of the population unannoyed in environments capable of potential hearing loss (Federal Interagency Committee on Urban Noise, 1980). Thus, management policies directed toward annoyance must consider that some level of annoyance may occur at even relatively quiet noise levels. Table II-2 summarizes some of the effects of noise on people. Additional sources of information are provided by Cohen and Weinstein (1981) and Lane (1986).

As shown in Table II-2, the range of sound levels is correlated with a distribution of expected annoyance. A large number of social surveys have verified the strong relationship between noise exposure level and the proportion of a community annoyed or highly annoyed. The relationship shown in these surveys produce what is alternately referred to as a noise/reaction, dose/reaction, dose/response, or simply response curve. As Cohen and Weinstein (1981) state:

smooth and nearly linear response curves are produced when the mean annoyance or the proportion deemed "highly annoyed" is plotted against noise levels.

TABLE II-2  
EFFECTS OF NOISE ON PEOPLE  
(Residential Land Uses Only)

Effects <sup>1</sup>	Hearing Loss	Speech Interference			Annoyance <sup>2</sup>	Average Community Reaction <sup>4</sup>	General Community Attitude Toward Area
		Indoor		Outdoor			
		% Sentence Intelligibility	Distance in Meters for 95% Sentence Intelligibility				
Day-Night Average Sound Level in Decibels	Qualitative Description				% of Population Highly Annoyed <sup>3</sup>		
75 and above	May begin to occur	98%	0.5		37%	Very severe	Noise is very likely to be the most important of all adverse aspects of the community.
70	Will not likely occur	99%	0.9		25%	Severe	Noise is one of the most important adverse aspects of the community environment.
65	Will not occur	100%	1.5		15%	Significant	Noise is one of the most important adverse aspects of the community environment.
60	Will not occur	100%	2.0		9%	Moderate to slight	Noise may be considered an adverse aspect of the community environment.
55 and below	Will not occur	100%	3.5		4%	Moderate to slight	Noise considered no more important than various other environmental factors.

1. "Speech Interference" data are drawn from the following tables in EPA's "Levels Document": Table 3, Fig. D-1, Fig. D-2, Fig. D-3. All other data from National Academy of Science 1977 report "Guidelines for Preparing Environmental Impact Statements on Noise, Report of Working Group 69 on Evaluation of Environmental Impact of Noise."

2. Depends on attitudes and other factors.

3. The percentages of people reporting annoyance to lesser extents are higher in each case. An unknown small percentage of people will report being "highly annoyed" even in the quietest surroundings. One reason is the difficulty all people have in integrating annoyance over a very long time.

4. Attitudes or other nonacoustic factors can modify this. Noise at low levels can still be an important problem, particularly when it intrudes into a quiet environment.

NOTE: Research implicates noise as a factor producing stress-related health effects such as heart disease, high-blood pressure and stroke, ulcers and other digestive disorders. The relationships between noise and these effects, however, have not as yet been quantified.

Source: Federal Interagency Committee on Urban Noise, 1980.

Furthermore, as first shown by Schultz (1978) the relationship revealed in these dose/response curves is fairly stable across different settings. Shultz was able to synthesize from a number of surveys and develop a single curve relating noise level to percentage highly annoyed. Job (1987) has shown that a remarkable consistency continues to exist across recent surveys.

The strong relationship demonstrated in dose/response curves can give the misleading impression that individual responses to noise are a simple function of sound level (Cohen and Weinstein, 1981). In fact, social survey data indicates that only a small proportion of the variance in self-reported annoyance can be attributed to changes in sound level (Fields and Powell, 1987). While sound level is a good predictor of the annoyance scores of groups, it is not a good predictor of whether an individual will be highly annoyed. Response to any given noise is a function of its meaning or significance, various characteristics of the receiver, and only to a limited extent by acoustic parameters (Cohen and Weinstein, 1981). Schomer and Neathammer (1984) also noted the poor data sets collected by many social surveys on indoor noise exposure or individual respondent life-styles. Thus, community response averages are believed to provide more meaningful information.

Table II-3 is taken from Job (1987) and summarizes the findings of 39 social surveys on the relationship between noise exposure and reaction. The table covers studies from ten countries and for nine different noise sources, which use a wide variety of noise indices and measurement techniques. Correlations are given for both individual reaction and an overall measure of group (community) reaction to noise exposure levels. This aggregation of grouped data includes a variety of reaction measures: the average of general reaction, the average annoyance, the percentage disturbed, the percentage highly disturbed, the percentage annoyed, the percentage highly annoyed, and the percentage seriously affected (Job, 1987).

Job's analysis of these 39 studies includes the following important conclusions:

- There is a strong similarity in dose/response relationships across measurement techniques and cultures.
- For individual data, noise exposure level accounted for only 9%-29% of the variation in response ( $r = 0.42 \pm 0.12$ ).
- The relationship with noise exposure level is much stronger for grouped data than for individual data.

The exception to the similarity in dose/response relationships across settings is for high intensity impulse sounds. In particular for the individual data, there were markedly reduced correlations between noise levels and response for impulse noise. An increased influence of attitude on response may provide an explanation (Job, 1987).

TABLE II-3  
RESULTS OF STUDIES ON THE DOSE/RESPONSE RELATIONSHIP

Study	County	Type of Noise	Sample Size	Correlation:	
				Individual Data	Group Data
Borsky, 1983	USA	Aircraft	942	0.58	
Bradley, 1978	Canada	Road	1,150	0.50	0.85
Bradley and Jonah, 1979	Canada	Road	300	0.49	
Bullen and Hede, 1984	Australia	Artillery	1,626	0.22	0.57
Bullen et al., 1985	Australia	Aircraft	624	0.58	
Fidell et al., 1983	USA	Quarry blasting	1,042		0.75
Fields and Walker, 1982	U.K.	Railway	1,453	0.46	
Gambart et al., 1976	Belgium	Road	247	0.61	
Garcia, 1983	Spain	Road	430		0.94
Grandjean et al., 1973	Switzerland	Aircraft	3,939	0.59	0.56
Grandjean et al., 1973	Switzerland	Road	944	0.43	0.95
Griffiths and Langdon, 1968	U.K.	Road	1,000	0.29	
Griffiths et al., 1980	U.K.	Road	222	0.44	0.88
Hall et al., 1979	Canada	Aircraft (general aviation)	292		0.86
Hall et al., 1979	Canada	Aircraft (commercial aviation)	673		0.84
Hall et al., 1979	Canada	Road	292		0.88
Hede and Bullen, 1982a	Australia	Aircraft	3,575	0.36	0.56
Hede and Bullen, 1982b	Australia	Rifle range	201	0.29	0.84
Kamperman, 1980	USA	Sonic boom	2,000		0.95
Langdon, 1976	U.K.	Road	1,359	0.21	0.96
Large and Ludlow, 1975	U.K.	Construction	535	0.52	0.85
Large and Ludlow, 1975	U.K.	Road	535	0.38	
McKennell, 1963 and 1973	U.K.	Aircraft	1,731	0.46	0.99
McKennell, 1978	U.K.	Aircraft (supersonic)	2,500 +	0.26	
Moehler and Knall, 1983	Germany	Road	525		0.66
Moehler and Knall, 1983	Germany	Railway	525		0.94
MIL Research, 1971	U.K.	Aircraft	4,699	0.40	
Murray and Avery, 1984	Australia	Quarry blasting	170	0.29	0.89
Rohrmann et al., 1973	Germany	Aircraft	660	0.56	
Rylander et al., 1972	Sweden	Aircraft	2,900		0.78
Rylander et al., 1976	Sweden	Road	811		0.78
Schomer, 1983	USA	Aircraft	231		0.89
Schumer and Schumer-Kohrs, 1983	Germany	Road	1,516	0.52	
Schumer and Schumer-Kohrs, 1983	Germany	Railway	1,516	0.46	
Seshagiri, 1979	Canada	Drop forging	609	0.30	
Shibuya et al., 1975	Japan	Road	939	0.36	
Sorensen and Magnusson, 1979	Sweden	Rifle Range	323		0.99
Taylor et al., 1980	Canada	Aircraft	21	0.40	
TRACOR, 1971	USA	Aircraft	3,590	0.37	
Mean			1,196	0.42	0.82
Standard Deviation			1,154	0.12	0.14

Source: Job, 1987.

This finding has been supported elsewhere, such as for sonic booms and Army base artillery noise (NRC, 1981). Management decisions concerning impulse noise will also be sensitive to the choice of the descriptor. C-weighted measures are more appropriate for impulse noises (Luz, Raspet and Schomer, 1985) and different sound levels will relate to community annoyance differently than for the A-weighted counterpart. Table II-4 relates the C- and A-weighted DNL's to the percentage of the population annoyed. If a maximum noise level were set at 65 DNL regardless of weighting factors, for A-weighted, 16 percent of the population would be annoyed, while 23 percent would experience annoyance using the C-weighted (TRADOC, 1982). Yet, a number of questions remain. Recent research by Schomer (1985) states that the exact functional relationship between the percentage of a community "highly annoyed" by impulse noise to CDNL remains in question. Fields and Powell (1987) found no significant difference between community reaction to impulsive and nonimpulsive helicopter noise.

### **Community Annoyance and Complaints**

As Duffy (1986) has noted, it is not excess noise that can bring legal, political, and economic pressure on a noisemaker. Rather, it is public reaction to noise that can affect change in a noisemaker's activities. While the strong functional relationship between noise exposure level and community annoyance has been established, the three-way relationship among noise, annoyance, and public complaint behavior also needs to be examined.

Some sources have posited a predictive relationship between complaint behavior and the prevalence of annoyance. A 1978 DOD publication, Planning in the Noise Environment, presents a summary of other sources, which depicts correlations between (1) complaint behavior and "normalized" DNL levels and (2) prevalence of annoyance with prevalence of complaints. For example, it is shown that when 1 percent of the people complain, 17 percent can be expected to be highly annoyed, and when 10 percent complain, 43 percent can be expected to be highly annoyed. However, these relationships should be taken skeptically. More recent evidence does not support a strong relationship between annoyance and complaints (Fidell, 1978; Luz, Raspet and Schomer, 1985).

It is valuable to examine some of the factors which are believed to be related to annoyance. To begin with, several items such as population density, and the prevalence of speech interference appear to be important correlates of exposure level and thus can be used as surrogates to exposure in predicting the prevalence of annoyance (Fidell, 1978). It is also evident that demographic factors such as age, sex, income, education, and occupational status are not significantly related to annoyance (Cohen and Weinstein, 1981; Fields and Powell, 1987). The factors other than exposure level which affect the dose/response relationship are often referred to as nuisance or intervening variables.



TABLE II-4  
POPULATION ANNOYANCE FOR C- AND A-WEIGHTED DNL

Percent of Population Highly Annoyed	C-Weighted DNL	A-Weighted DNL
1	45	45
2	46	49
2	47	49
2	48	49
3	39	52
3	50	52
3	51	52
4	52	54
4	53	54
5	54	56
6	55	57
7	56	58
8	57	59
9	58	60
10	59	61
12	60	63
14	61	64
16	62	65
18	64	67
20	64	68
23	64	69
25	66	70
28	67	72
32	68	73
35	69	74
39	70	76
42	71	77
46	72	78
50	73	79
54	74	80
58	75	81

Source: U.S. Army Training and Doctrine Command, 1982.

As Fields and Hall (1987) note:

The large amount of variance in annoyance which is unexplained by the various acoustical factors has led to a number of hypotheses about personal and other attitudinal factors which might be associated with noise annoyance responses.

Job (1987) has concluded that general noise sensitivity and attitude toward the noise source may modify reaction to noise. Bullen, Hede, and Kyriacos (1986) have also shown that personal sensitivity will substantially affect noise reaction. Fields and Powell (1987) have noted that in both their own short-term annoyance to helicopter noise study and in other long-term studies, individual responses are related to a number of attitudinal variables. These attitudinal variables included perceptions of danger from the noise source, beliefs about the preventability of the noise, and feelings about the local area. Cohen and Weinstein (1981) suggest that the ability to predict and control the occurrence of noise affects both physiological and psychological response.

In distinguishing between complaint behavior and annoyance, Cohen and Weinstein (1981) have noted that annoyance may lead to public action, but again there are a number of variables that may intervene. While there is no general organizing theory for these intervening variables and their effect on the relationship between annoyance and complaints, a number of items can be identified. Synthesizing from social survey results, Fields and Hall (1987) list six conditions which lead to complaints.

- (1) There is a basic underlying dissatisfaction with the existing noise situation.
- (2) There is an identifiable object or authority that is recognized as being in some respect responsible for the noise or the control of noise.
- (3) There is a belief that group or individual action can lead to a change in the noise situation.
- (4) People must be aware of a means for contacting the appropriate authority.
- (5) The introduction of a new focal point (e.g. Concorde) can substantially increase the amount of action.
- (6) Social structure characteristics of an area and of society as a whole must facilitate public action (e.g. on the community level, there is a greater likelihood of action if the community members interact with each other and there is a commitment to the community).

Complaints, unlike annoyance, have been shown to be related to a number of socioeconomic variables such as education, occupation, and income. Attitude toward the noise has also been found to affect complaint behavior (Fields and Hall, 1987).

One recent study done by Luz, Raspet, and Schomer (1985), and based on an analysis of community complaints to aircraft and weapons noise, has challenged the

accepted Army model of noise and complaint behavior. The traditional model has two essentially similar forms. In the first, complaints are seen as a symptom of annoyance, and increases in DNL lead to increases in both annoyance and complaints. In the second, complaints are believed to directly result from annoyance, and increases in DNL lead to increases in annoyance which causes increases in complaints.

Based on their analysis, and the earlier work of Schultz (1978), an alternative model of complaint behavior is suggested. Annoyance is seen as a function of both average noise level and average physiological arousal. Complaints are seen as being a function of arousal only and not necessarily correlated with DNL. All of these alternative models of complaints are shown in Figure II-5.

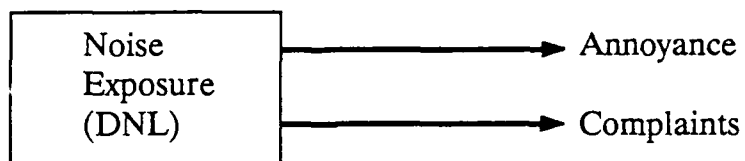
Increases in arousal are the input in a behavioral "black box" that leads to complaints. This process is thought to be similar to the concept of dishabituation in behavioral psychology. Luz, Raspet, and Schomer (1985) sum up the process in five basic points.

- (1) People habituate to a broad range of noise levels and will stop responding to noise.
- (2) People unconsciously compare new noises to expectations of the typical level and become aroused if it differs.
- (3) Arousal is an unpleasant state, and some sort of rational action will be pursued to prevent its reoccurrence (a complaint).
- (4) If the complaint fails to achieve its goal, increased emotional arousal will result. Eventually this unpleasant state will begin to extinguish.
- (5) As emotional arousal extinguishes, some other type of directed behavior will be adopted (litigation or political pressure). Individuals may also decide to leave a noise-impacted area.

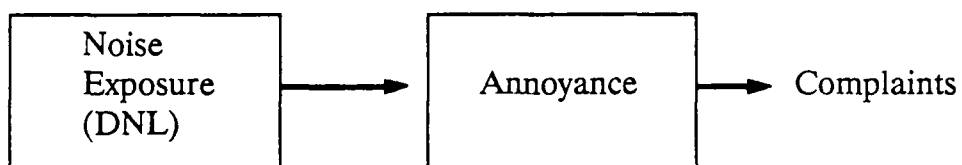
As a point of additional reference, Fidell (1981) presents an informative discussion on the use of behavioral black box theories in noise research.

The analysis of complaints by Luz, Raspet, and Schomer (1985) supports noise abatement (reduction) policy based on an assessment of the level of annoyance rather than the number of complaints. Annoyance can exist without complaints, and conversely, complaints may exist without adverse noise levels. In a personal interview, Schomer (1988) noted that noise management policy geared solely to handling complaints may set itself up for problems, such as establishing bad precedents. Bullock (1988) has described a situation at Sea-Tac International Airport characterized by a concentrated effort of 13 to 14 years toward property acquisition and abatement, shrinking noise zones, and yet there is a recent increase in complaints and pressures from areas outside the noise zones.

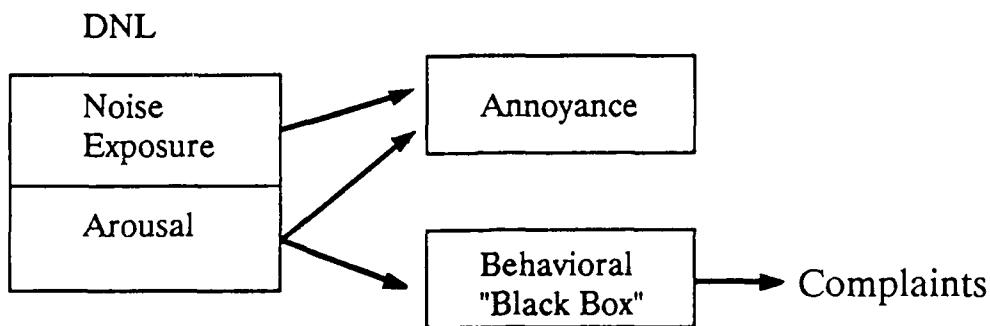
## A. COMPLAINTS AS SYMPTOM OF ANNOYANCE



## B. COMPLAINTS AS A RESULT OF ANNOYANCE



## C. COMPLAINTS AS RESULT OF AROUSAL

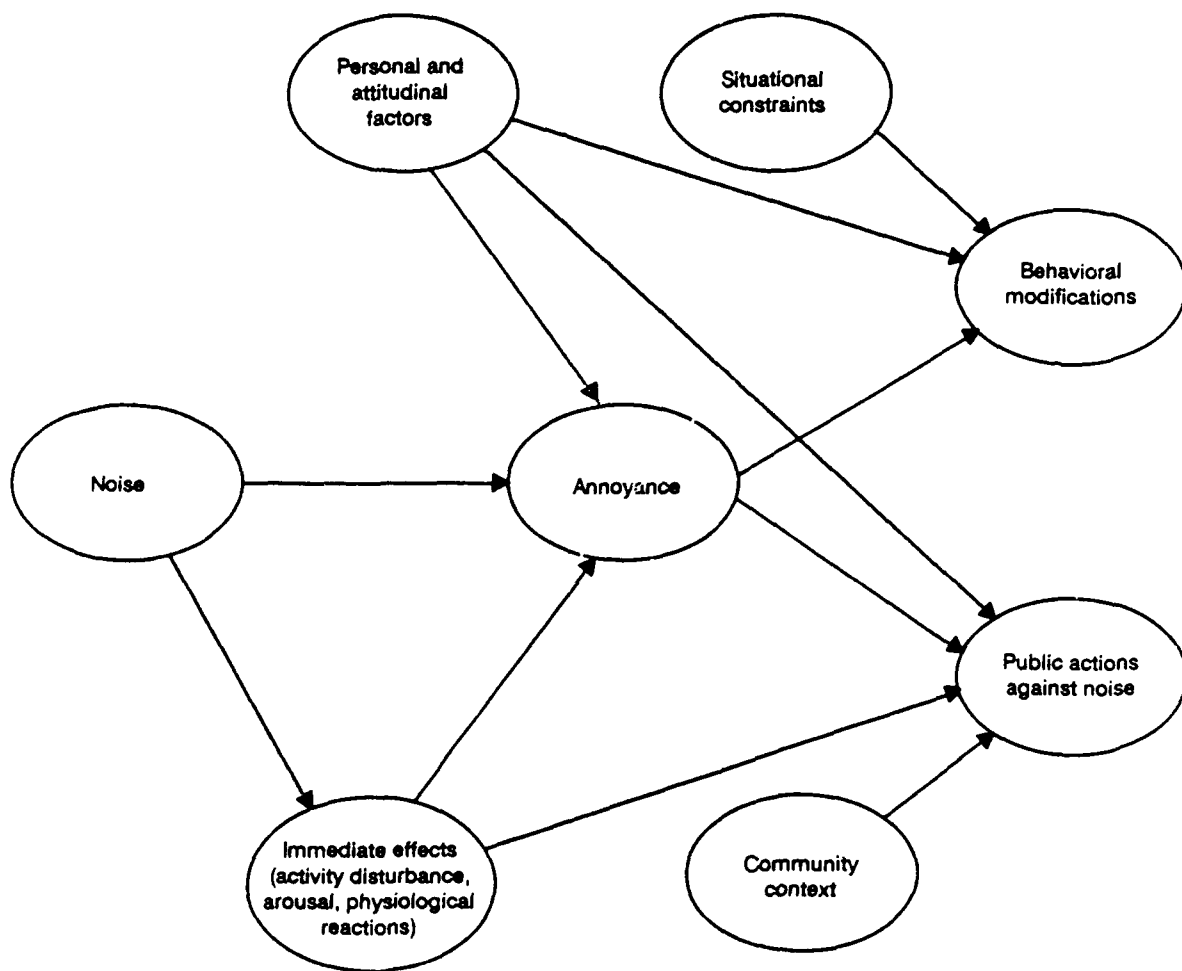


Source: Luz, Raspet and Schomer, 1985.

Figure II-5. Alternative Complaint Models

## Discussion and Summary

A general model summarizing the hypothesized interactions between noise exposure, and the multi-faceted phenomenon of human response to noise is presented in Figure II-6. The range of human response includes arousal, annoyance, complaints, and possibly behavioral modifications such as leaving a location or mitigating noise impacts through medication. It is evident that human response to noise must be considered in a wholistic framework that considers situational constraints, personal attitudes, and community context.



Source: Adapted from Fields and Hall, 1987.

Figure II-6. Relation Between Noise and Human Response

The management application of a noise metric is an attempt to accurately describe the full noise environment. Impulse noise requires special consideration such as the use of a C-weighted descriptor. While the relationship between community annoyance and noise exposure level is strong, the relationship between complaints and either annoyance or noise exposure is unclear. It does seem evident that noise abatement (reduction) policies must be geared to annoyance rather than complaints. Many noise management actions are often complaint driven; Public action can impact noisemaking activities, and complaint activity records may be accepted as indicators of noise impacts. However, the current body of evidence indicates that complaints are an inadequate indicator of the full extent of noise effects on a population (Fields and Hall, 1987).

Finally, there are a variety of technical issues that can be raised concerning the usage of noise descriptors. For example, time-of-day weighting in noise descriptors remains a controversial issue. Bullen and Hede (1985) state that "time-of-day weighting used in most exposure measures are [sic] shown to be less than optimal." While Schomer and Neathammer (1985) argue that the descriptor for impulsive noise should include a nighttime adjustment factor. However, issues such as these do not appear to be of sufficient magnitude to justify management policy "paralysis" while further refinements are being assessed.

### **III. THE LEGAL FRAMEWORK FOR NOISE MANAGEMENT**

The objective of this chapter is to provide an overview of the legal framework for noise management. Statutory and case law combine to shape management policy choices. This overview will aid in the understanding of the noise management programs described in the succeeding chapter.

Civil litigation resulting from damages caused by excessive noise levels has increased dramatically over the last 30 years. This is in part a result of the continued "urban sprawl" into areas which have historically been relatively insensitive to activities that generate high levels of sound. These sound levels, which in the past may have been acceptable, become "noise" when adjacent land uses conflict with one another. The classic example of this, and the most often litigated, is the conflict between airports and adjacent landowners. Recent federal court decisions have put airport owner-proprietors in the unenviable position of being solely liable for certain noise-related damages. In addition to the flurry of civil litigation, which has set precedents in determining the grounds for seeking compensation for noise damages, a plethora of state and federal laws have been enacted to control noise. These laws regulate noise in the workplace, on the roads, and in the air. Many of them deal with specific sources of noise such as automobile and truck engines and tires, jet engine design and size, various appliances, and industrial equipment. Other laws such as the Federal Tort Claims Act permit suits in the federal courts for previously uncompensable injuries against the government.

A brief examination of the federal statutes which attempt to regulate noise, either directly or indirectly, will be made. The interpretation of some of these laws by the courts and the legal theory under which compensation is sought will follow. The primary cases that will be analyzed are three United States Supreme Court cases, all of which involve airport noise. Airport noise cases, in addition to being the most frequently litigated, are worthy of note for two important reasons, as noted by Engleman and Raspet (1983). These cases have set several important precedents which may apply to other noise sources, and they are of particular relevance to the military.

#### **FEDERAL LEGISLATION PERTAINING TO NOISE CONTROL**

##### **Military Claims Act of 1942**

The Military Claims Act was enacted in part to authorize compensation for property damage of up to \$1000 as a result of firing damage, regardless of fault (Rouse, 1986). Claims are dealt with under the noncombat activities provision of the act, and claimants need only show causation and damages rather than negligence. The act

allows for an administrative remedy and does not provide for any judicial recourse (Rouse, 1986). However, separate negligence charges are sometimes brought under the Federal Tort Claims Act, which will be discussed later.

### **Federal Aviation Act of 1958**

The Federal Aviation Act authorized the federal regulation of airspace and air commerce by the Federal Aviation Administration (FAA) and the Civil Aeronautics Board (Werlich, 1981). The original act did not, however, specifically authorize the FAA to regulate airport noise emissions. In 1968, the act was amended in part by Section 611, which recognized a noise problem and granted authority to the FAA to establish standards and regulations limiting noise emissions by aircraft. Significantly, this amendment authorized regulation of aircraft as opposed to airports (Werlich, 1981).

Shortly after the amendments, the FAA responded with the promulgation of "FAR Part 36" (Werlich, 1981). Federal Air Regulation, Part 36 (14 C.F.R. Section 36 [1981]) provided for a standard of measurement of established maximum allowable noise levels for new aircraft. Since 1969, Part 36 has been amended to cover all jet-powered and propeller-driven aircraft (Werlich, 1981).

### **National Environmental Policy Act of 1969 (NEPA)**

The act requires that all federal agencies carry out a prescribed Environmental Impact Statement process for any proposed federal action which may significantly affect the quality of the environment, including noise (Federal Interagency Committee on Urban Noise, 1980).

### **Federal Aid Highway Act of 1970**

This act requires that federally-aided highways consider noise control in their planning and design. The act was later amended to require the Federal Highway Administration to provide funding for noise mitigation on existing highways (Federal Interagency Committee on Urban Noise, 1980).

### **Occupational Safety and Health Act of 1970 (OSHA)**

This act sets forth standards governing excessive noise in the workplace of interstate enterprises. OSHA rules permit exposure to noise in terms of a given



duration of time workers may be exposed to certain levels of noise. When noise levels exceed those which are permitted for even a very brief time, regulations require that protective measures be implemented (Cheremisinoff and Ellerbusch, 1982).

### **Airport and Airways Development Act of 1970 (AADA)**

In 1970, Congress recognized that the existing airport system was inadequate to meet projected future needs and in response passed the Airport and Airways Development Act. The AADA authorized a 10-year program which gave federal matching grants to airport proprietors for certain types of development projects (Werlich, 1981). The projects which were eligible for this money included construction and land and easement acquisitions. However, noise abatement projects were excluded from the list. In 1976, the AADA was amended to broaden the definition of "airport development" to include projects which mitigated noise. These included physical barriers, landscaping to diminish noise, and purchases of land for noise attenuation purposes (Werlich, 1981). The amendment provides that funds will not be granted unless the airport proprietor has given fair consideration to the interests of the communities in or near the development (Bennett, 1982). This implies a requirement to consider the effects of the airport on the health and welfare of the community (Bennett, 1982).

### **Noise Pollution and Abatement Act of 1970**

The passage of this act was the first concerted effort to control noise at the national level. The act established a Noise Abatement and Control office within the federal Environmental Protection Agency (EPA). This office was responsible for investigations and research into noise pollution matters in order to develop recommendations for legislation (Edelman and Genna, 1985). The Noise Control Act of 1972 was passed in part because of the findings of this office.

### **Noise Control Act of 1972**

The Noise Control Act brought the full attention of the EPA to bear upon the problem of noise pollution. The act gave the U.S. EPA the authority to develop noise control methods, set noise standards, and to coordinate and supervise the noise control programs of other federal agencies (Cheremisinoff and Ellerbusch, 1982). The states retain overall responsibility for control of environmental noise, but federal action is authorized to control noise at its source.

### **Federal Aviation Administration's Noise Abatement Policy of 1976**

The FAA appears to have interpreted congressional intent when it issued this policy in 1976 (Werlich, 1981). It stated that the FAA, while maintaining control of airspace use and management of aircraft noise at its source, disclaimed any liability for noise damage by giving the power to protect its citizens through land use controls and police power to the state and local governments (Werlich, 1981). Single liability for noise damage resides with the airport proprietor, while shared responsibility for aviation noise abatement resides jointly among federal, state, and local governments; air carriers; and airport proprietors (Werlich, 1981).

### **Quiet Communities Act of 1978**

This act amended the 1972 Noise Control Act in several areas, with the overall goal to encourage noise control programs at the state and local levels. The amendments include the following provisions:

- States may petition for stricter product standards.
- Civil penalties are prescribed as not to exceed \$10,000/day.
- The EPA is authorized to provide direct assistance to communities and states in the form of grants, training and technical assistance, and research and development programs (Cheremisinoff and Ellersbusch, 1982).

### **Aviation Safety and Noise Abatement Act of 1979 (ASNA)**

Congress furthered its attempts at pervasive controls over airport noise with the passage of the Aviation Safety and Noise Abatement Act. ASNA required the secretary of transportation to develop federal standards for monitoring the impacts of noise generated by airports on nearby residents (Werlich, 1981). The act states airport proprietors may submit "noise exposure maps" and "noise compatibility programs" to the secretary for approval. However, the legislation clearly states that the U.S. government is not "liable for damages resulting from aviation noise by reason of any action taken by the Secretary or the Administration of the Federal Aviation Administration under this section" (Werlich, 1981). Significantly, this act did not address what liability, if any, an airport proprietor should have for noise damage to adjacent property.

As was mentioned earlier, laws that indirectly affect noise litigation are those permitting civil suits against the federal government, as in the case of the Federal Tort Claims Act or the Tucker Act. In the case of these laws, a private citizen can bring the government to court if they can prove a violation of their constitutional rights or negligence-based damages. It is these laws which have permitted the three major court decisions that are to be discussed (Engleman and Raspet, 1983).

## CASE LAW

Despite the large number of laws which are intended to regulate noise at its source and to encourage land use management to mitigate the adverse effects of noise, there has been a great deal of litigation involving noise-related injury. Since 1946, the U.S. Supreme Court has decided three aircraft noise cases which have established the basis for determining the liability of airport owner-proprietors, whether they are owned by the federal government, a local government, or by a private party. These cases are *U.S. v. Causby*, *Griggs v. Allegheny County*, and *Burbank v. Lockheed Air Terminal*.

The 1946 Supreme Court case of *U.S. v. Causby* was the first of these three cases which challenged the constitutionality of inflicting excessive noise levels on the public. The case involved a poultry farmer who brought suit against the U.S. Air Force alleging that the full use and enjoyment of his property had been taken from him because of frequent low flights by Air Force aircraft over his farm. The farmer contended that his property had been taken from him without compensation and that the Air Force had violated his Fifth Amendment rights. The Court stated that although the airspace is part of the public domain, flights which are so frequent and low as to "be a direct and immediate interference with the enjoyment and use of the land" did constitute a taking (Werlich, 1981). It is significant in *Causby* that the aircraft flight path was directly over the plaintiff's property. In the Tenth Circuit Court in the case of *Batten v. United States*, Section 306 F2d. 580, 585 (10th Cir., 1962), the court held that where the government did not operate jets directly over the property, and therefore did not physically invade the property, there was no taking. This was in spite of the fact that there was an interference with the use and enjoyment of the property, such as dishes and windows rattling (Setter, 1980-81). Two important legal theories were applied to noise-based damages in *Causby*. They are trespass and inverse condemnation (Engleman and Raspet, 1983).

The trespass theory relies largely on a physical invasion of private property. However, in this case, the Court in *Causby* ruled that it was the overflight and the low altitude which had combined to constitute the invasion (Engleman and Raspet, 1983). The Court's recognition of the inverse condemnation argument was based on its judgment that the excessive noise had resulted in a taking of private property without compensation. Although the government may take over private property for public use through its exercise of eminent domain, it must compensate the landowner before use begins (Engleman and Raspet, 1983). The combination of these two theories has permitted other suits against the government on the basis that a trespass by the government was so excessive as to take the property from its owner.

Sixteen years after *Causby*, the Supreme Court again granted certiorari to a case involving airport noise. In *Griggs v. Allegheny County*, the plaintiff Mr. Griggs filed suit against Allegheny County as the operator of the Greater Pittsburgh Airport. The

aircraft using the airport flew so low and in such close proximity to the Griggs' home that the plaintiff was forced to move. The Court reasoned that the owner of the airport was responsible for acquiring land adjacent to the airport to reduce the impact of the noise, and if it failed to do so, it was liable for the resulting aircraft noise damage (Werlich, 1981). The local government, and not the FAA, had established a navigational easement over the plaintiff's property by reason of the direct overflights, thus it was the airport proprietor who was liable for compensatory damages (Bennett, 1982). The Court in *Griggs* took the *Causby* decision a significant step further. *Causby* held that noise-based damage claims in combination with trespass could be awarded (Engleman and Raspet, 1983). However, *Griggs* went on to clearly state who was liable for causing the damage; as between the airport proprietor and the Federal Aviation Administration, the responsibility lies with the proprietor. A dissenting opinion by Justice Black argued that the FAA as an agency of the federal government should be liable for the damages because Congress had preempted control of the airspace as the exclusive right of the federal government (Bennett, 1982). However, Congress appears to have supported the majority in this decision, as can be seen in some of the legislation following the *Griggs* case. The Noise Control Act of 1972, for example, emphasized that federal action is essential when dealing with "major noise sources in commerce, control of which requires national uniformity of treatment," however, "the primary responsibility of noise rests with state and local governments" (Bennett, 1982). It is noteworthy that the Noise Control Act applies to a wide variety of noise-generating activities and not solely to aircraft or airports.

The *Griggs* decision indicates that it is the responsibility of the owner-operators of noise-producing activities to consider the effects of the noise on adjoining land uses. Further, that in the event damage does occur as a result of their siting or operation, they may be held liable for compensating the injured (Engleman and Raspet, 1983).

The third Supreme Court case was in 1973. *Burbank v. Lockheed Air Terminal* established that a local government which did not own the airport, cannot regulate air traffic by virtue of its police powers. The city of Burbank had imposed a curfew on aircraft operations at Lockheed Air Terminal in an attempt to control the noise impact of aircraft taking off and landing there (Engleman and Raspet, 1983). The Court held that it was beyond the scope of the city's police power to regulate aircraft in flight, since this is the sole province of the federal government (Engleman and Raspet, 1983). The Court in *Burbank* introduced yet another complexity to the precedents set in the two earlier cases. In the much-cited footnote 14, found in the majority opinion, Justice Douglas hinted that a municipality which was also the airport proprietor had some power to regulate that a nonproprietor municipality might not have (Werlich, 1981). This "proprietor exception" has contributed greatly to the present confusion as to who may restrict air travel with the intent of controlling noise. Based on *Burbank*, nonproprietors are preempted by the federal government, although the extent to which a municipality that is proprietor may go in regulating aircraft operation is, as of yet,

undecided by the Supreme Court. A California court relied on footnote 14 of the *Burbank* decision in *Air Transport Association v. Crotti* when it decided that because *Griggs* had determined airport proprietors are responsible for damage to private property as a result of aircraft using their facilities, the proprietors have a concomitant right to control use of their airports (Werlich, 1981).

The implications that can be drawn from *Burbank* for other noise-producing sources seem to be simply that those activities which are responsible for meeting federal requirements pertaining to the source of the noise cannot be regulated by any lower police-power agency (Engleman and Raspet, 1983).

Further analysis of the cases involving airport noise liability versus noise control responsibility is beyond the scope of this report. The direction that courts, both state and federal, appear to be taking is toward a full burden of liability on the proprietor of noise-producing activities for those damages which are compensable. However, many courts have relied on the "proprietor exception" to the federal preemption argument in order to retain for the proprietor some control over the use of their facilities.

## **IV. NOISE MANAGEMENT PROGRAMS IN THE UNITED STATES**

The purpose of this chapter is to examine some of the primary noise management programs in the United States. First, a summary of seven major federal programs will be presented. Second, the topic of identifying noise zones will be addressed. Third, there will be a separate discussion on each of the individual noise management programs. Finally, a brief examination will be made of other, less prominent, noise programs.

### **SUMMARY OF PROGRAMS**

Table IV-1 provides a summary of the principal federal agency noise management programs. A common goal of these programs is to protect the health and welfare of individuals impacted by noise. Most of the agencies also have specific additional objectives which recognize that noise issues can affect agency policies (Federal Interagency Committee on Urban Noise, 1980).

The summary table was developed by the Federal Interagency Committee on Urban Noise (1980) and has been updated here to reflect current conditions. The original table was designed to briefly overview noise policies and programs relating to land use. Column seven, summarizing the OSHA noise program, has been added to the original six programs covered. While the OSHA noise program is not directly related to land use, it does share the common element with the other programs of basing program policies on specified noise levels.

Differences in programs can be described in terms of the type and intent of the noise levels specified. Three distinct types of levels can be identified.

- (1) Mitigation levels (FHWA design levels)
- (2) Health effects level (EPA source levels, OSHA workplace levels)
- (3) General planning or land use levels (FAA, DOD), which might also be tied to federal assistance programs (HUD, VA)

Each type of level is designed to achieve a specific purpose and, if misused can produce erroneous results (Federal Interagency Committee on Urban Noise, 1980; NRC, 1977).

### **IDENTIFYING NOISE ZONES**

Noise management policies are commonly linked to a set of chosen noise levels. The effect of this on land use management is that land can be classified into noise zones.

TABLE IV-1  
FEDERAL AGENCY POLICY AND PROGRAM SUMMARY

Agency	1. Department of Defense (DOD)	2. Department of Housing and Urban Development (HUD)	3. Environmental Protection Agency (EPA)	4. DOT/Federal Aviation Administration (FAA)	5. DOT/Federal Highway Administration (FHWA)	6. Veteran's Administration (VA)	7. Occupational Safety and Health Administration (OSHA)
Type of program or policy	Air Installations Compatible Use Zones (AICUZ) and Installation Compatible Use Zones (ICUZ) programs	HUD Noise Regulations	Health & Welfare Guidance	Aviation Noise Abatement Policy; FAR Part 150 Airport Noise Compatibility Planning Program	Highway Noise Policy	VA Noise Policy	Occupational Noise Regulations
Key documents	DOD Instruction 4165.57 (1977); Installation studies; AR 200-1	24 CRP Part 51B (1979); The Noise Guidebook 1985	EPA "Levels" Document 1974; EPA Program Summary 1980	DOT/FAA Aviation Noise Abatement Policy (1976); Advisory Circular 150/5050-6 (1977); Advisory Circular 150/5020-1 (1983)	FHPM 7-7-3 (1976); The Audible Landscape 1974	Section VIII Appraisal of Residential Properties Near Airports (1988)	29 CFR 1910.95 B 1985
Noise Levels (Title and Purpose of)	Levels used as "reasonable" guidance to communities in planning	Levels which determine whether proposed site are eligible for HUD insurance or assistance	Levels which are required to protect the public health and welfare with an adequate margin of safety	Levels used as "starting points" in determining noise/land use relationships	Design noise levels	Levels determining whether proposed sites are eligible for VA assistance	Levels determining whether feasible administration or engineering controls shall be utilized

TABLE IV-1  
FEDERAL AGENCY POLICY AND PROGRAM SUMMARY  
(continued)

Agency	1. Department of Defense (DOD)	2. Department of Housing and Urban Development (HUD)	3. Environmental Protection Agency (EPA)	4. DOT/Federal Aviation Administration (FAA)	5. DOT/Federal Highway Administration (FHWA)	6. Veteran's Administration (VA)	7. Occupational Safety and Health Administration (OSHA)
Noise Levels  (Purpose of)	Guidance to communities for planning. Reflects cost, feasibility, past community experience, general program objectives, and consideration of health and welfare goals.	See above. Levels can be used as general planning levels. Reflect cost, feasibility, general program objectives, and consideration of health and welfare goals.	These levels identify in scientific terms the threshold of effect. While the levels have relevance for planning, they do not in themselves form the sole basis for appropriate land use actions because they do <u>not</u> consider cost, feasibility, or the development needs of the community. The user should make such tradeoffs.	Guidance to communities for planning. Reflects safety, cost, feasibility, general program objectives, and consideration of health and welfare goals.	These levels are used in determining where noise mitigation on a particular highway project is warranted. They do reflect cost and feasibility considerations. They are not appropriate land use criteria. Location-specific.	See above. Reflects cost, feasibility general program objectives, and consideration of health and welfare goals.	These levels shall be used to protect employees from adverse noise in the workplace. Administrative and engineering controls to noise exceeding the prescribed levels are required only if the benefits are determined to be greater than costs.
Source to which applied	Military airfields AICUZ) and installations (ICUZ)	All sources	All sources	Civil airports	Highways only	Airports only	All sources
Noise descriptors used	DNL	DNL	DNL	DNL, (CNEL, California only)	L <sub>eq</sub> or L <sub>10</sub> for design hour	Various (including DNL)	TWA (time-weighted average)

Source: Adapted from Federal Interagency Committee on Urban Noise, 1980.



An understanding of noise zones will aid in the discussions of the individual management programs.

Noise zones are physically defined on a map by isopleth lines or "noise contours." The levels which define the zones are constant but the shape of the zones on the map will change as the noise environment changes. Table IV-2 presents a set of noise zones, classified by noise levels, for a variety of commonly used descriptors. The ability to identify current and predicted noise zones arms the noise program manager with a powerful tool for noise compatible land use planning.

## **NOISE MANAGEMENT PROGRAMS**

### **Department of Transportation/Federal Highway Administration (DOT/FHWA)**

The FHWA noise program is part of the overall environmental assessment process for the Federal Highway program (which is administered individually by the states). As required by NEPA and the Federal Aid Highway Act of 1970, the FHWA is "concerned with traffic and construction noise associated with Federal aid highways" (Federal Interagency Committee on Urban Noise, 1980). The primary noise sources are automobiles and trucks.

Noise analysis is performed on two types of highway projects: new construction and existing highways receiving complaints. The majority of the analyses are performed on new construction sites. This includes both new locations and significant changes (in either vertical or horizontal construction) to existing highways. The analysis focuses solely on the effects of highway noise, and if this impact is insignificant then noise abatement measures are considered to be "not reasonable and feasible" (Armstrong, 1988).

The focus of FHWA noise policy is on providing noise mitigation as determined by design noise levels (using the  $L_{eq}$  and  $L_{10}$  noise metrics). These levels can be defined as:

noise levels for various activities or land uses which represent the upper limit of acceptable traffic noise level conditions. These levels are used to determine the degree of impact of traffic noise on human activities (FHWA, 1980).

The vast majority of mitigation is in the form of structural walls or barriers to attenuate noise. Other approaches considered, but rarely used, include traffic-flow measures and the retrofitting of noise sensitive public establishments with insulation or the installation of air conditioning (Armstrong, 1988).

TABLE IV-2  
IDENTIFICATION OF NOISE ZONES

HUD & DOD Noise Zones	Standard Land Use Coding Manual Noise Zones	Noise Exposure Class	Noise Descriptor		
			DNL Day-Night Average Sound Level	L <sub>eq</sub> (hour) Equivalent Sound Level	NEF Noise Exposure Forecast
Zone I Acceptable	A	Minimal exposure	Not exceeding 55	Not exceeding 55	Not exceeding 20
	B	Moderate exposure	Above 55 Not exceeding 65	Above 55 Not exceeding 65	Above 25 Not exceeding 30
Zone II Normally Unacceptable	C	Significant exposure	Above 65 Not exceeding 70	Above 65 Not exceeding 70	Above 30 Not exceeding 35
			Above 70 Not exceeding 75	Above 70 Not exceeding 75	Above 35 Not exceeding 40
Zone III Unacceptable	D	Severe exposure	Above 75 Not exceeding 80	Above 40 Not exceeding 80	Not exceeding 45
			Above 80 Not exceeding 85	Above 80 Not exceeding 85	Above 45 Not exceeding 50
			Above 85	Above 85	Above 50

Sources: Adapted from Magan, 1979; and Federal Interagency Committee on Urban Noise, 1980.

The FHWA also has a limited role in noise source reduction and noise compatible land use management. In the area of noise source reduction, the FHWA supports improved highway design and implements interstate motor carrier noise regulations as issued by the EPA. In the area of land use management, the FHWA provides information and guidance to local communities, the basic recommendations being contained in The Audible Landscape (FHWA, 1974).

#### **Department of Transportation/Federal Aviation Administration (DOT/FAA)**

The Federal Aviation Administration (FAA) deals with all aviation noise at all airports in the United States (Starley, 1988).

Noise management in the FAA is based on the Aviation Noise Abatement Policy (ANAP) of 1976, and the Aviation Safety and Noise Abatement Act (ASNA) of 1979. The ANAP defines the "responsibilities of FAA, air carriers, airport operators, and local communities in achieving reductions in airport noise" (FAA, 1983).

The FAA noise management program consists of two basic parts: noise source reduction and providing guidance and assistance (both technical and financial) to local communities for noise compatible land use planning. The reduction of noise from individual aircraft includes a program for retrofitting or replacing older noisier aircraft (referred to as Type II) with newer quieter aircraft (Type III). Approximately two-thirds of the commercial fleet are Type II aircraft. Federal Aviation Regulation (FAR) Part 36 requires a noise certification for different aircraft types. Newly designed and manufactured are generally required to be significantly quieter than older aircraft (FAA, 1983). Operational procedures to reduce noise from takeoffs and landings are also part of the program (Federal Interagency Committee on Urban Noise, 1980).

The second part of the FAA noise management program is concerned with land use planning in the areas adjacent to airports. FAR Part 150 implements Title I of the ASNA of 1979. More specifically, it provides a single system for the measurement of airport noise and of individual exposure to airport noise. In addition, it establishes a standardized Airport Noise Compatibility Planning Program. The Part 150 program replaces an earlier interim program known as the Airport Noise Control and Land Use (ANCLUC) planning studies (FAA, 1983).

The current planning program includes four basic components (FAA, 1983):

- (1) Provision for the development and submission to the FAA of Noise Exposure Maps and Noise Compatibility programs by airport operators
- (2) Standard noise units, methods, and analytical techniques for use in airport assessments

- (3) Identification of land uses that are normally compatible (or incompatible) with various levels around airports
- (4) Procedures and criteria for FAA approval or disapproval of noise compatibility programs

The Airport Noise Compatibility Planning Program encourages interaction between all involved parties (airport operator, airport users, airport neighbors, local land use control jurisdictions, and the FAA). However, the program does not "interfere with established prerogatives of State and local governments concerning land use and related noise compatibility actions and responsibilities" (FAA, 1983). The Part 150 program is discussed further in Chapter V.

### **The Veteran's Administration (VA)**

The VA noise program is concerned with taking airport and air base noise impacts into account in the provision of loan guarantees to residential properties. The program applies to military veterans and active duty personnel. Eligibility for VA home loan assistance is dependent on a property's relationship to three recognized noise zones. Established noise levels define the zones, and the criteria for determining eligibility are similar to those of the HUD. The VA noise zones and specific limitations which apply to VA guaranteed loans are shown in Table IV-3. They have been taken directly from Section VIII of the Appraisal of Residential Properties Near Airports (VA, 1988).

The basic objectives of the VA Loan Guaranty Noise Policy are (1) to protect the federal government interests in guaranteeing loans for veterans and (2) to guarantee the salability of properties acquired back through foreclosures (Widener, 1988). The VA (1988) recognizes

the possible unsuitability for residential use of certain properties  
and the probable adverse effect on liveability and/or value of  
homes in the vicinity of major airports and air bases.

The adverse effects of noise are considered on an individual case basis and included in the market data analysis in the appraisal process.

The VA loan guarantee program has been in place since 1944, and the noise program since 1969. The staff officers of the 49 regional offices are responsible for the implementation of the noise policies. However, private fee appraisers are the contact people out in the field, and their actions must be reviewed by the regional offices.

TABLE IV-3  
VA NOISE ZONES AND ASSISTANCE CRITERIA

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Noise Zones

- 1: Under 65 DNL
- 2: 65-75 DNL
- 3. Over 75 DNL

Specific Limitations

- A. Proposed or existing properties located in noise zone 1 are generally acceptable as security for VA guaranteed loans.
  - B. Proposed construction to be located in noise zone 2 will be acceptable provided:
    - (1) Sound attenuation features are built into the dwelling to bring the interior DNL of the living unit to 45 decibels or below.
    - (2) There is evidence of market acceptance of the subdivision in which the property is to be located.
    - (3) The veteran-purchaser signs a statement which indicates his/her awareness that (a) the property being purchased is located in an area adjacent to an airport, and (b) the aircraft noise may affect normal livability, value, and marketability of the property.
  - C. Proposed subdivisions to be located in noise zone 3 are not generally acceptable. The only exception is a situation in which the VA has previously approved a subdivision, and the airport noise contours are subsequently changed to include the subdivision in noise zone 3. In such cases, the VA will continue to process loan applications provided the requirements above are met.
  - D. Existing dwellings in noise zones 2 and 3 are not to be rejected because of airport influence if there is evidence of acceptance by a fully informed veteran.
-

## Department of Housing and Urban Development (HUD)

The HUD noise program is directed toward achieving the goal of a "decent home and suitable living environment for every American family" (as originally established in the Housing Act of 1949) and supporting the noise control efforts of other federal agencies. The HUD noise program is primarily concerned with transportation noise and its effect on HUD-assisted dwelling units. This constitutes about 15 percent of all new construction (Miller, 1988).

The foundation for the HUD noise program is based on noise regulation 24 CFR Part 51B. Eligibility for HUD mortgage insurance and other assistance is based on the identification of property's placement within one of three possible noise zones: acceptable, normally unacceptable, and unacceptable. These zones are identified according to exterior noise levels or standards. Construction attenuation requirements are geared for achieving an interior noise level of 45  $L_{dn}$  (HUD 1985).

The basic site acceptability standards for HUD assistance are shown in Table IV-4. Specific regulations are found in The Noise Guidebook (HUD, 1985). In the application of its site acceptability standards, HUD distinguishes between (1) new construction, (2) existing construction, and (3) modernization and rehabilitation.

TABLE IV-4  
HUD SITE ACCEPTABILITY STANDARDS

Noise Zone	Day-Night Average Sound Level (in Decibels)	Special Approval and Requirements
I. Acceptable	Not exceeding 65 dB (1)	None
II. Normally unacceptable	Above 65 dB but not exceeding 75 dB	Special approvals, Environmental review, Attenuation (2)
III. Unacceptable	Above 75 dB	Special approvals, Environmental review, Attenuation (3)

Notes: (1) Acceptable threshold may be shifted to 70 dB in special circumstances.  
(2) Five dB additional attenuation required for sites above 65 dB but not exceeding 75 dB.  
(3) Attenuation measures to be submitted for approval on a case-by-case basis.

Source: HUD 1985.

The HUD noise management program is conducted by the appraisers at the approximately 40 field offices. In addition, each office also has an environmental officer who is involved (Miller, 1988).

The HUD general policy also requires that noise considerations be an integral part of HUD-assisted community planning and grant programs. Comprehensive Planning Assistance grantees must examine both noise sources and the level of noise exposure in the urban environment. Recipients of both Community Development Block Grants (CDBG) and Urban Development Action Grants (UDAG) are also required to consider HUD noise criteria in the environmental review process (HUD 1985).

#### **U.S. Department of Labor/Occupational Safety and Health Administration (OSHA)**

The OSHA noise program is aimed at protecting workers from excessive occupational noise. Employers are legally responsible for keeping the workplace free from excess noise. Estimates for the total number of U.S. workers exposed to hazardous noise have gone as high as 14 million (Cheremisinoff and Ellerbusch 1982).

Employee exposure to noise in the workplace is governed by regulations promulgated by the Secretary of Labor under the authority of the Occupational Safety and Health Act of 1970. The regulations were based on earlier standards developed pursuant to the Walsh-Healey Act (Bennett, 1986).

The foundation for occupational noise control is contained in 29 CFR 1910.95B, 1985. In short, when employees are subjected to noise levels in excess of certain standards and longer than specified durations over the workday, then employers are required to implement feasible administrative and engineering controls. The basic standards are listed below (Bennett, 1986).

Duration/Day, Hours	Sound Level dBA (Slow Response)
8	90
6	92
4	95
3	97
2	100
1.5	102
1	105
0.5	110
0.25	115

An example of an administrative control within the workplace would be operational or scheduling changes. Engineering controls would include physically reducing the noise at the source or deflecting the flow of sound. Should these controls fail to provide sufficient noise level reduction, then personal hearing protection equipment must be provided to the workers (Bennett, 1986).

### **Environmental Protection Agency (EPA)**

The EPA's noise program formerly played a leadership role in coordinating federal agency noise management efforts. Today, EPA involvement in the area of noise management has been greatly reduced.

The EPA's Office of Noise Abatement and Control (ONAC) was initiated in 1972. ONAC was then disbanded in 1982 by the Office of Management and Budget (OMB) under the Reagan administration.

Under the Noise Control Act of 1972, the EPA was tasked with developing noise level criteria for the protection of public health and welfare. These general noise standards were published in what is referred to as the EPA "levels" document (EPA, 1974). The basic levels are shown in Table IV-5. While they include an adequate margin of safety, no consideration is given to cost and feasibility.

In developing the noise level criteria, "the EPA drew upon a large body of survey data describing the degree of activity interference and resulting annoyance for a variety of noise levels" (HUD, 1984).

The major components of the noise program under ONAC included:

- Promulgating noise regulations for major noise sources such as trucks, motorcycles, interstate carriers, and air compressors
- Assisting state and local governments in developing noise ordinances
- Proposing aircraft/airport standards to the FAA
- Promoting and engaging in research (EPA, 1979)

The initial thrust of the EPA noise program was on establishing noise source emission standards. (These standards remain in force today.) With the passage of the Quiet Communities Act of 1978, the focus of the EPA program shifted to providing technical assistance to state and local governments (Federal Interagency Committee on Urban Noise, 1980). Current EPA activities in noise management include disseminating public information and reviewing federal EIS's for noise considerations.



TABLE IV-5  
SUMMARY OF EPA NOISE LEVELS

Hearing Loss	$L_{eq}(24)$	70 dB	All areas
Outdoor activity interference and annoyance	$L_{dn}$	55 dB	Outdoors in residential areas and farms; other outdoor areas where people spend widely varying amounts of time; and other places in which quiet is a basis for use
	$L_{eq}(24)$	55 dB	Outdoor areas where people spend limited amounts of time, such as school yards, playgrounds, etc.
Indoor activity interference and annoyance	$L_{dn}$	45 dB	Indoor residential areas
	$L_{eq}(24)$	45dB	Other indoor areas with human activities such as schools, etc.

The hearing loss level identified here represents annual averages of the daily level over a period of 40 years. (These are energy averages, not to be confused with arithmetic averages.)

EPA has determined that for purposes of hearing conservation alone, a level which is protective of that segment of the population at or below the 96th percentile will protect virtually the entire population. This level has been calculated to be an  $L_{eq}$  of 70 dB over a 24-hour period.

Source: NRC, 1977.

## Department of Defense (DOD)

Focal points for noise management within the Department of Defense (DOD) are the compatible land use programs (Air Installation Compatible Use Zones-AICUZ and Installation Compatible Use Zones-ICUZ). DOD Instruction 4165.77 (1977) is the basic policy statement for these programs. An AICUZ or ICUZ study is initiated at individual installations to describe noise exposure and land use in adjacent communities and to investigate solutions to real or potential noise conflicts.

The Federal Interagency Committee on Urban Noise (1980) has outlined the following basic points in the Department of Defense noise management policy statement. Specifically, DOD policy:

- Requires that all reasonable, economical, and practical measures will be taken to reduce and/or control the generation of noise from aircraft
- Is to work toward achieving compatibility between air installations and neighboring civilian communities by means of a compatible land use planning and control process conducted by the local community
- Requires working with local governments, local planning commissions, special purpose districts, regional planning agencies, state agencies, and state legislatures as well as other federal agencies
- Includes technical assistance to local, regional, and state agencies to assist them in developing their land use planning and regulatory processes, to explain an AICUZ or ICUZ study and its implications, and generally to work toward compatible planning and development in the vicinity of military airfields and installations

The compatible use zone programs are the primary vehicles for influencing local land use. Each study will require some degree of public interaction, and these study processes are discussed in greater detail in Chapter V. As shown in the above DOD policy outline, interacting with local communities is only one portion of noise management in the DOD. Within each of the services, noise management is pursued in a variety of both permanent and temporary forms. In general, these actions can be classified into basic noise and noise impact research, noise abatement and mitigation, and assistance provided to outside (nonmilitary) parties. As an example of the full range of activities and associated resource requirements, Table IV-6 lists the major noise management activities within the U.S. Air Force, as provided by Herb Dean (1988) of the Air Force Environmental Division. The table also illustrates that the individual services will pursue areas of research and noise management of particular interest to their respective missions. For example, as shown, the Air Force conducts a sonic boom research program (at Wright Patterson AFB in Ohio). Whereas the U.S. Army has pursued research in blast noise and helicopter noise at the Construction Engineering Research Laboratory (CERL) in Illinois.

TABLE IV-6

## NOISE MANAGEMENT ACTIVITIES WITHIN THE U.S. AIR FORCE

- 
1. The Air Installation Compatible Use Zone Program
    - Ninety-one of 108 Air Force bases are actively involved in the AICUZ program.
  2. The Environmental Impact Analysis Process
    - This process is covered under Air Force Regulations 19-2 (continental U.S.) and 19-3 (overseas).
  3. Noise and Sonic Boom Impact Technology (NSBIT) Program.
    - This is a \$13 million, five-year, R & D program.
  4. DOD Interservice Committee on Sonic Boom Issues
  5. NATO Committee on the Challenges of a Modern Society (CCMS)
    - This study of civil and military aircraft noise is co-sponsored by the U.S. and the Federal Republic of Germany, and has 11 NATO countries participating.
  6. Hush House Program
    - The Air Force is completing a program for approximately 125 hush houses at a cost of approximately \$400 million for and improvements and equipment.
  7. Air Force Regulations (AFR) 55-34 Reducing Flight Disturbances
    - This regulation includes the supersonic waiver process which governs the establishment of supersonic flight operations below 30,000 feet mean sea level.
  8. Guidelines for Assessing the Noise Impact of Air Force Flying Operations (1984)
    - These guidelines, requested by the Air Force Secretariat, are to be supplemented by the results of short and long research.
  9. The Installation Planning Process (e.g. Base Comprehensive Plan [BEP], Air Installation Compatible Use Zone [AICUZ] study, Range Planning)
  10. The Sonic Boom Reporting System
  11. Public Affairs Fact Sheets (e.g. Sonic Boom)
  12. Educational Courses/Materials
    - (E.g. audio-visual: aircraft noise)
    - Air Force Institute of Technology courses
    - Sonic boom evaluation (cassette)
    - Airbase and environmental planning
    - Environmental protection committee course
    - Airspace managers' course
  13. Individual Responses to Public Complaints, Claims, or Litigation
- 

Source: Developed from a personal communication with Herb Dean (1988).

## OTHER NOISE PROGRAMS

In addition to those already reviewed, a number of other federal agencies have also been involved in noise research and noise control. These agencies include the National Aeronautics and Space Administration (NASA), the U.S. Department of Interior (DOI); the U.S. Department of Agriculture (DOA); the U.S. Department of Health, Education and Welfare (HEW); and the U.S. Department of Commerce/National Bureau of Standards (DOC/NBS). The focus of these agencies has primarily centered on basic noise and noise effects research (Cheremisinoff and Ellerbusch, 1982).

While the focus of this chapter is on federal programs, the states have also played a role in noise management. Two areas to be noted are state noise ordinances, and state workmen's compensation laws.

At least 44 of the 50 states have noise ordinances of the nuisance-type variety, based on general terms such as "excessive" (Mulholland, 1985). Although, as Cheremisinoff and Ellerbusch (1982) have noted, in recent years state regulations in the form of sound level limits have been used increasingly. In 1982, they cited 16 states which have promulgated sound level limits for on-the-road vehicles and seven states with property line sound level limits for industrial and commercial fixed facilities.

As would be expected, the most densely populated states have been the most active in the area of noise control. One prominent example is the state of New Jersey where the Department of Environmental Protection's Office of Noise Control has enforced statewide stationary source noise regulations since 1974 (DiPolvere, 1987). Christiansen et al. (1986) describe a large-scale (\$3.6 million) retrofit program for an industrial facility in New Jersey which was completed in compliance with state authority. New Jersey has also enacted content-specific state zoning regulations for noise compatibility (Knack and Schwab, 1986).

In the area of workmen's compensation and industrial protection of workers, all the states have statutes covering hearing loss. But only a handful actually award compensation for any appreciable number of hearing loss claims (Cheremisinoff and Ellerbusch, 1982).

Numerous local municipalities have enacted noise ordinances. Pre-1950 efforts in local noise control focused on protecting tranquility in public places and enacting nuisance-type laws. The use of quantitative standards within ordinances began in the 1950s (Bragdon, 1974). In the 1970s, prompting by the EPA was the impetus for a large number of communities to enact model local noise ordinances. In many cases administrative enforcement has always been weak. However, the role of local communities in noise control is not limited to noise ordinances. Chapter VI reviews noise compatible local land use management.

## **V. THE IDENTIFICATION AND EVALUATION OF NOISE MANAGEMENT TECHNIQUES**

### **INTRODUCTION**

The purpose of this chapter is to examine the different noise mitigation techniques available, with particular emphasis on those useful to the military. The techniques are divided into four major categories: physical techniques, organizational measures, public relations/interaction measures, and administrative measures. The reader should note that the lines of distinction between categories are often blurred for individual techniques. For example, it may be difficult to differentiate between an administrative action, such as regulating emissions, and an operational or organizational action. This is especially true in the case of the military, which is both the noise source and the administrative or regulatory authority. Yet, it is believed that the categories provide a useful framework for examining noise management techniques.

Physical techniques can be subdivided into two broad areas: technological and operational measures. Technological measures are those which actually reduce noise levels at the source or alter the noise path enroute to the receiver. Operational measures are designed not necessarily to change noise levels but to alter the impact on the receiver. The techniques covered are applicable to the military as well as other organizations such as airport proprietors.

Organizational measures are designed to improve the form and function of noise management programs. Emphasis is placed on the creation of roles and responsibilities within a noisemaking organization and/or noise management program. This section is subdivided into three areas: (1) the structure of the decision-making process, (2) program support, and (3) program training.

The third category, public relations/interaction measures, emphasizes the need for interaction with local communities and provides specific techniques useful to enhance community involvement and relations. Three programs that emphasize public involvement, FAR Part 150, used by the FAA, and the AICUZ and ICUZ, programs of the Department of Defense, are examined.

Finally, administrative measures are techniques used by military installations, regulatory agencies, or local municipalities to directly regulate an action or to solicit a response which will mitigate noise impacts. Administrative measures consist of two types, direct and indirect controls. Direct controls consist of the regulation or prohibition of some activity, while indirect controls pertain to financial incentives or other actions designed to solicit a desired response by some group. Administrative measures are expounded on in more detail in Chapter VI.

The scope and length of this chapter are necessary to provide a perspective on the broad range of management techniques available for noise mitigation.

## **PHYSICAL MEASURES**

Physical measures for noise abatement are those which directly impact the noise source, path, or receiver. This can be separated into two distinct sections, technological and operational. Technological measures involve an alteration of the noise source or path and include such aspects as quieter designs, the use of barriers and enclosures, acoustical modification of the noise path by design or construction techniques, and an emergent technology known as active noise control. Operational measures are those which involve a change in the operation of the source but not necessarily the noise level created. The goal of this technique is to reduce the noise impact on the receiver.

The following discussion is simply a description and a general overview of the different technological and operational measures available for the primary noise sources of the military: aircraft, impulse, vehicle, and fixed-facility noise. Since noise abatement is often technically complex and source-specific in nature, the following discussion should enhance the planner's perspective on the problem, but is not meant as a comprehensive review.

### **Technological Measures**

Technological measures are referred to as those measures which actually reduce noise levels by altering the noise source or noise path enroute to the receiver. For the military, often the primary objective of the equipment is performance. Quieter designs can mean decreased performance which may impair mission capabilities. Occasionally, the available technological measures to reduce noise will be employed when stealth is preferred over performance. The following provides a brief overview of the types and applicable technological fixes available to reduce noise levels of military equipment.

### **Techniques for Military Noise Sources**

One of the more noticeable noise sources in both the military and civilian environment is jet aircraft. Unlike commercial aircraft which have become much quieter in the last 10 to 15 years, military aircraft are more powerful and noisier than ever before (Zusman, 1988). Since mission capabilities can be jeopardized if aircraft are forced to employ noise reduction measures, programs such as AICUZ mentioned in the previous chapter are employed.

Unlike military fixed-wing aircraft, rotary-wing aircraft are more amenable to technological change that will not jeopardize performance. Noise reduction measures for rotary-wing aircraft concentrate on two predominant noise sources, blade slap and rotor rotational noise (DOD, 1978). According to Helicopter Association International (1983) blade slap is described as:

...when a blade intersects its own vortex system or that of another blade. When this happens, the blade experiences locally high velocities and rapid angle-of-attack changes. This can momentarily drive a portion of the blade into compressibility and possibly shock stall, both of which produce aerodynamic loading variations. Either or both mechanisms generate sound.

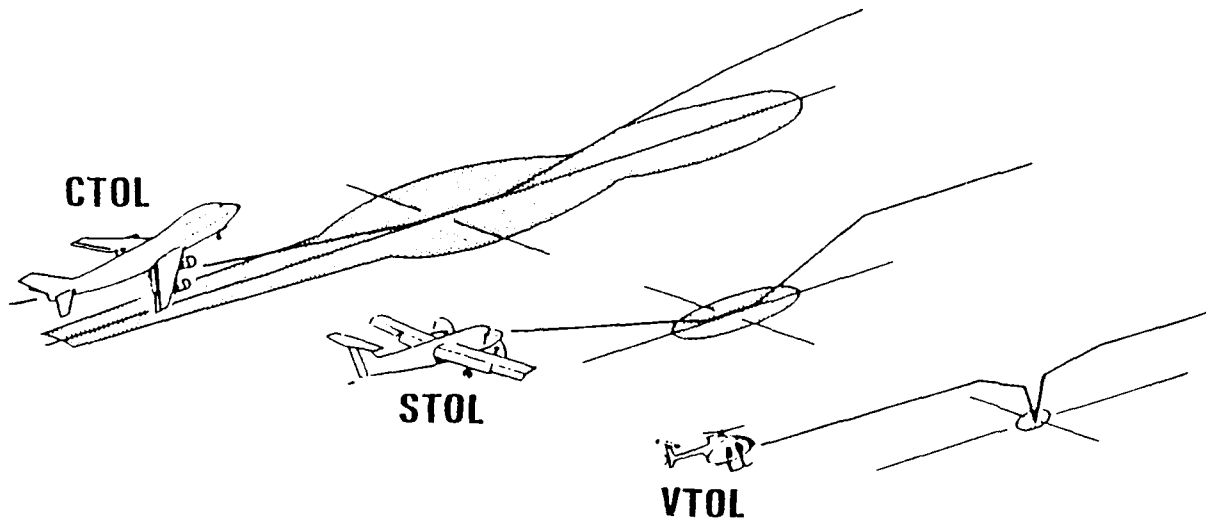
Decreased rotor speed can reduce blade slap and additional blades will allow similar lift capabilities at the reduced rotor speeds (DOD, 1978). Additionally, auxiliary engines for forward flight can reduce dependence on the rotor and also reduce noise levels.

An emergent technology is the tilt-rotor aircraft which takes off and lands like a helicopter but flies like a fixed-wing aircraft (Starley, 1988). This aircraft combines attributes of both the rotary- and fixed-wing aircraft and can greatly reduce noise exposure from takeoffs and landings. This technology is referred to in the military as short takeoff and landing (STOL). This aircraft, which uses a shorter portion of the runway, can greatly reduce noise exposure levels. Vertical takeoff and landing (VTOL), characteristic of helicopters, can reduce the noise exposure during takeoff by even greater levels. Figure V-1 illustrates the difference in the noise exposure footprint for conventional takeoff and landing (CTOL) versus VTOL and STOL.

Technological advances will continue to provide the possibility for quieter aircraft which maintain high performance. Planners must be aware of how this will change the noise environment.

The noise source that is more pervasive on military installations than in the civilian sector is impulse noise. Impulse noise most often refers to blast noise from weapons and sonic booms from supersonic aircraft. It is the result of a sound pressure wave which rapidly peaks and then decays slowly, and in the case of sonic booms, peaks once again (DOD, 1978). Because of the low-frequency vibrational characteristics of impulse noise, C-weighted noise indices are used (Luz, Raspet and Schomer, 1985).

For weapons such as artillery, sound mitigation is not easily accomplished. Most technological measures usually have an effect on mission capability, such as decreased range of artillery rounds (Schomer, 1988). Raspet (1981) did find the use of aqueous foam somewhat successful in reducing demolition noise and artillery blasts. Reductions of up to 14 dB for unconfined blasts are possible.



Source: Helicopter Association International, 1983.

Figure V-1. Difference in Noise Exposure Area for Different Aircraft Types

The reduction of the effects of sonic booms because of overflights of supersonic aircraft is even less amenable to technological modifications. Operational changes such as restricting flight paths, limiting flight hours, and increasing flight altitudes are recommended procedures for coping with sonic boom problems (DOD, 1978).

A noise source often more receptive to noise control than the previous sources is vehicular noise. Proper maintenance of muffler systems and regular servicing to keep the vehicles operating efficiently can help in reducing noise. In noise sensitive environments, strict regulation of noisy vehicles in the form of inspections or police-type enforcement may be necessary. Operators must be made aware of the need for efficiently maintained equipment (DOD, 1978).

Often vehicle maintenance will not suffice when a large volume of traffic is involved, as is the case for large training missions. Smoothly paved and well-maintained roads are the major methods of noise mitigation in this instance. Operational procedures such as reduced speeds and rerouting may also be potential solutions. Operational options for reducing noise levels will be discussed in detail later in this chapter.



The final general noise source, fixed-facility noise, is often a product of the machinery in the facility. As with vehicular noise, proper maintenance can keep noise levels at a minimum.

According to Goff and Novak (1977) a number of limited measures can be taken. They are:

- (1) Eliminate impacting surfaces
- (2) Balance moving parts
- (3) Reduce friction
- (4) Apply dynamic absorbers
- (5) Vibrational isolation
- (6) Alteration of natural frequency of system
- (7) Structural damping
- (8) Isolation of large radiating panels
- (9) Perforations in large radiating panels

The purchase of quieter designed equipment is also possible. In instances where the source cannot be quieted, hearing protection or the utilization of enclosures may be necessary.

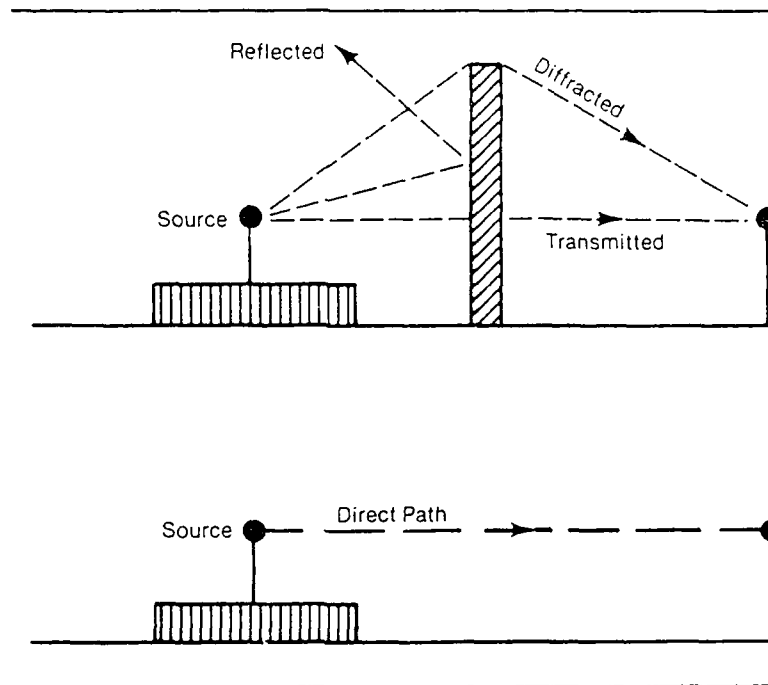
### **Overview of Specific Technological Measures**

Several specific methods are predominantly used in providing the technological control of the noise sources previously described. The following is a description and discussion of the specific methods used to provide noise attenuation.

#### **Barriers**

One technological method often used for noise reduction is barriers. Barriers can consist of walls, earthen berms, natural terrain, buildings, or foliage. Noise reduction is achieved by reflecting, diffracting, or partially absorbing the sound waves. Barrier effectiveness increases with height, width, and proximity to the receiver (FHWA, 1980d).

Basically, a barrier redistributes sound energy into three paths: (1) a diffracted path over the top of the barrier, (2) a transmitted path through the barrier, and (3) a reflected path away from the receiver. Figure V-2 illustrates the effects of barriers on these three paths. The total effect of barrier installation depends on the sound energy along the original path as compared to the energy along these three directed paths.



Source: HUD, 1985.

Figure V-2. Alteration of Noise Paths by a Barrier

The first of these three paths is diffraction. For an infinitely long barrier, one which sound must go over or through, diffraction is the bending of sound waves over the top. Attenuation is accomplished by increasing the length the sound must travel and by creating a "shadow zone" behind the barrier. The attenuation by an increased distance for a point source can be determined using the inverse square law expressed as:

$$L = 10 \log \frac{r_o^2}{r_1}$$

where

- $L$  = the reduction in dBA
- $r_o$  = is the reference distance between source and receiver
- $r_1$  = changed distanced between source and receiver

Based on this formula a "rule of thumb" is for every doubling of distance between  $r_o$  and  $r_1$  a six dB reduction occurs (FHWA, 1980b).

For a line source such as highway traffic, the equation is

$$L = 10 \log \frac{r_o}{r_1}$$

In this case a doubling of the source-receiver distance will represent a three dB reduction in sound levels (FHWA, 1980b). Both equations represent the effect of spreading the sound over a greater area and thereby weakening the sound intensity. The predominant level of noise reduction is achieved by creating a "shadow zone," a zone where the sound waves do not occur. The shadow zone is directly related to the diffraction angle (FHWA, 1980d). This angle will increase either with barrier height or with a closer location to the source or receiver.

For instances when the barrier does not completely shield the source from the receiver, often the case for highway barriers, sound energy can be received around the ends. Additionally, any gaps or openings, such as accesses, can result in an increase in noise levels for receivers near the opening. This is because of a buildup of sound energy which escapes through the opening (Mulholland, 1985).

The second characteristic of a barrier that can be a potential benefit or a detriment to noise attenuation is reflection. For a single wall barrier the idea is to reflect the noise away from the receiver. However, any receivers on the reflected side will experience an increase in noise levels which will be less than three dBA, since a single reflection can at most double the sound energy (FHWA 1980d). Multiple wall barriers can have the effect of multiple reflections.

Multiple reflection can often be eliminated through the design of barriers whose angles are greater than 10° to 15° from vertical (FHWA, 1980b). Space limitations can prevent steep sloped barriers from being used. Stapleton International Airport in Denver, Colorado, has 30-foot high walls at 70° angles at one end of the airport. The steep angled walls prevent reflection problems and have reduced noise levels by 60 percent (Alverson, 1988).

The use of material that absorbs sound waves can also decrease reflection. Sound absorption takes place when sound waves entering a material have their energy converted to heat.

The degree to which absorption occurs for a given material is denoted by the material's absorption coefficient. A value of 1.00 is absolute absorption, while a coefficient of .60 means that 60 percent of the sound energy is absorbed and 40 percent is reflected (Cheremisinoff and Ellerbusch, 1982).

The final characteristic of noise barriers involves sounds that do not travel around or over the barrier but travel through. The transmission of sound through the barrier depends on the characteristics of the barrier material (weight, stiffness, and loss factors), the angle of incidence of the sound, and the frequency spectrum (FHWA, 1980b). The ability of a material to transmit noise is known as the transmission loss, TL. TL is related to the mass per unit area of the material for a finite frequency range. It can be expressed as:

$$TL = 13 + 14.5 \log m$$

where

TL = transmission loss, dB

m = mass per unit area of the barrier, Kg/m<sup>2</sup>

Above the frequency range, stiffness of the barrier must be considered, and below the range both stiffness and resonance come into play (Marraccini, 1987).

Barriers can be applied to several of the noise sources in the military. Limited applications are available for aircraft noise, since they are only effective when the aircraft is on the ground. Noise from taxiing, takeoffs, and landings can be reduced, and they are also useful in abating thrust reversal noise (DOD, 1978).

The application and success of barriers for aircraft are limited. Denver's Stapleton Airport, as previously mentioned, constructed a barrier which reduced noise levels by 60 percent (Alverson, 1988). The Minneapolis-St. Paul Airport contains a one-mile-long, 15-foot high earth berm with 25-foot-high trees planted 60 to 100 feet deep which achieves a five dB minimum reduction (DOD, 1978).

The effects of barriers on rotary aircraft are not well understood (Schomer, 1988). Barrier effectiveness is less than with fixed-wing aircraft because of the vertical ascent capabilities of rotary aircraft. A barrier's main effectiveness, whether for rotary- or fixed-wing aircraft, is during ground operations.

Barriers are also not really applicable to any type of impulse noise other than small arms fire, for which they are used quite extensively. For weapons such as artillery, the sound waves are transmitted upward and later focused downward miles away (DOD, 1978). Unless the barrier is located extremely close to the source, sound waves transmitted along the ground will likely reflect the noise to other sources. Barriers are ineffective in preventing the vibrational effects of impulse noise.

Probably the most extensive use of barriers is for motor vehicles. This is the primary management tool employed by the FHWA (Armstrong, 1988). Many different

types of materials are used along highways. The material type used most extensively in the United States is concrete block. The berm/concrete combination is the most common combination material barrier (FHWA, 1987).

Attenuation levels over 20 dB are considered nearly impossible for highway noise barriers (FHWA, 1980b). The finite length of barriers and the space limitations often limit maximum attenuation. Buildings along roadways can also provide sound attenuation. Multiple rows of building can provide an effective 10 dB reduction in noise level with the first row of houses, if spaces are less than 40 percent, then only a 3 dB reduction. Each additional row of buildings provides a 1.5 dB reduction in noise levels. This is also assuming that the first row of buildings are as tall or taller than the buildings farther from the source (FHWA, 1980b).

Landscaping or the planting of dense woods and vegetation along roadways or training routes can be effective in achieving noise reductions. If the woods are dense enough that no clear line of sight exists between the source and receiver, at least five dBA attenuation can be expected if the woods are 30 meters deep. An additional 30 meters will result in an additional five dBA reduction. However, regardless of the thickness or configuration, only a maximum reduction of 10 dBA can be expected (Barry and Reagan, 1978). A mixture of evergreen and deciduous trees is preferred to provide effective sound reduction year around.

Often natural terrain can provide natural barriers, or roadways can be depressed or elevated to achieve noise reductions. The concept of diffraction is used with these methods to increase the distance the sound must travel to the source. The Department of Defense (1978) provides examples for calculating noise attenuation possibilities.

According to DOD (1978), several costs and benefits must be considered before the use of barriers as an abatement tool can be used. The benefit-cost analysis should include the following:

- (1) Benefits
  - Noise reduction and related benefits
  - Privacy
  - Less dirt, glare, and exhaust
- (2) Costs
  - Mission degradation
  - Direct (design and construction)
  - Maintenance (landscaping, cleaning, repairing, etc.)
  - Safety (to motorists, pilots, etc.)
  - Visual (esthetically displeasing, block view)

For vehicles in field training, barriers may not be feasible and could possibly degrade mission capabilities. Barriers can also be costly. Table V-I presents the costs of highway barriers for the top 10 states in highway barrier construction. The average cost per mile was \$774,727.00 in 1986 dollars.

TABLE V-1  
COST OF HIGHWAY BARRIERS FOR THE TOP TEN STATES

State	Length in Miles	Cost in 1986 Dollars (Millions)	Cost per Mile (Dollars)
California	148.1	116.5	786,630
Minnesota	47.6	41.6	873,949
Colorado	31.2	26.6	852,564
Virginia	26.2	21.5	820,610
Oregon	20.8	16.3	783,654
Michigan	18.6	13.2	709,677
Arizona	17.1	13.0	760,234
New York	17.1	10.2	596,491
New Jersey	15.8	8.9	563,291
Washington	14.5	8.7	600,000
Ten-state total	356.9	276.5	774,727

Source: Adapted from FHWA, 1987.

### Enclosures

Enclosures are similar to barriers except that they completely enclose the source. The physical concepts are the same: reflection, absorption, and transmission are the main principles that reduce noise levels. The term "sound insulation" is often confused with absorption. Insulation concerns the reduction of the sound as it passes through the enclosure, while absorption involves the degradation of sound into heat energy. Insulation can be achieved without any such degradation (Mullholland, 1985). In its

most basic form, a barrier simply absorbs as much sound energy as possible and reflects the rest for later absorption and reduction throughout the increased distance traveled from the reflection. If the barrier material is not a good sound absorber, the energy level in the enclosure will build up until it equals the amount of sound energy generated by the source and the sound will emanate as if the enclosure did not exist. Good absorbers can absorb 90 percent of the incident sound energy (Mullholland, 1985).

Because of the accumulation of sound energy in the enclosure, individuals gaining access into the enclosure must wear protective hearing devices. Additionally, ducts or other openings must be included with the enclosure to allow the dissipation of built-up heat energy into waste heat (Mulholland, 1985).

Enclosures have limited applicability for military uses. Their primary use is for machinery in fixed facilities, hush houses for run-ups of jet aircraft, and indoor shooting ranges for small arms fire. As with barriers, they may also be used to reduce noise impacts from generators or motor pools in densely urbanized areas. By far the most expensive employment of enclosures is for hush houses. Hush houses are special enclosures used near runways to perform engine runups on aircraft. The Air Force is currently completing a program of 125 hush houses at a cost of approximately \$400 million (Dean 1988). Individual hush houses can carry a price tag of \$5 million (Hamill, 1988).

### Acoustic Modification

Acoustic modification can be used to alter the path of the noise energy or to dull the perceptions of an intruding noise. There are four basic categories as listed below.

- |                                   |                           |
|-----------------------------------|---------------------------|
| (1) Acoustic site design          | (3) Acoustic Construction |
| (2) Acoustic architectural design | (4) Noise Masking         |

(1) Acoustic site design involves maximizing the use of distance reflection and shielding for a given design. Structures and other land uses are positioned within the confines of the site to achieve minimum noise exposure.

Buffer zones can be used in site design to separate noise sensitive zones from less sensitive ones. Often parks or open fields are situated near noise sources, or homes are located in the back of the lot to obtain the maximum distance from the source.

Proper acoustic site design involves the minimization of the reflection of noise off ground surfaces and buildings. Methods such as utilizing absorbent surfaces on landscapes (such as grass instead of blacktop or concrete near the source) varying building heights, and reducing building density can weaken reflections (FHWA,

1980b). Additionally, the orientation of reflective structures to focus reflected noise into nonsensitive areas can be effective.

According to FHWA (1977), a final aspect of acoustic site design is the use of shielding. Barriers or berms attractively designed into the landscape can be an effective method. Furthermore, buildings less sensitive to noise can act as barriers or shields for the more sensitive ones. A building itself can be positioned so that the less sensitive areas such as the garage can serve as shielding (Goff and Novak, 1977).

(2) Acoustic architectural design involves the shielding of sound waves by the structure itself. Basically, there are three approaches:

- Reduction of opening and surface area (doors, windows, and ventilation ducts)
- Use of external architectural elements (balconies, overhangs, etc.)
- Use of interior space (DOD, 1978)

The walls of a structure act to some extent as a sound barrier. However, openings such as doors, windows, and ventilation ducts can also allow unwanted sound energy to enter the structure. Doors, windows, and ducts can be eliminated in parts of the structure exposed to intrusive noise or designed to limit inside exposure (Goff and Novak, 1977). Often something as simple as the installation of air conditioning can eliminate noise problems, since windows can be closed to prevent noise intrusions. External architectural elements such as balconies and overhangs can be utilized as noise shields. However, care must be taken in placement to prevent a reflection of the noise into the building (DOD, 1978).

Space utilization is the final element of architectural acoustic design. This is similar to the practice of using other buildings to act as shielding except the structure itself is used. More noise sensitive areas can be located away from the noise source while less sensitive areas are nearer. For example, a school near a highway may place the gymnasium and shop near the highway while classes are positioned on the opposite side.

(3) Acoustic construction involves the use of additional structural elements to impede the transmission of sound. Table V-2 provides some possible construction techniques that can be used.

Acoustic construction is required for VA loans for new structures in the 65-70 dB sound level zone, zone II (Widener, 1988). The U.S. Department of Housing and Urban Development provides a similar stipulation for support. They, however, first recommend the use of barriers or land use planning, since acoustic construction will not



TABLE V-2  
ACOUSTIC CONSTRUCTION TECHNIQUES

Element	Construction Technique
Walls	Increase mass Use dead air space Increase air space width between walls Use staggered studs Seal cracks and edges Use insulation blankets Use resilient materials to hold studs and panels together Use acoustic coating
Roofs	Increase mass Seal cracks and edges
Ceilings	Use insulation blankets Use nonfixed suspension methods Use acoustic coating
Floors	Increase mass Block of joints to prevent noise from traveling over or under walls Use resilient support between joists and floor
Windows	Seal Increase thickness Double glaze Increase volume of airspace in double-glazed windows
Doors	Use solid core Doorframe gaskets

Source: Goff and Novak, 1977.

Interior noise levels are set at 45 dB by HUD. Standard construction is assumed to provide 20  $L_{dn}$  of sound attenuation which would meet the 45  $L_{dn}$  interior noise standard for a 65  $L_{dn}$  exterior noise level. Above 65  $L_{dn}$  and below 75  $L_{dn}$  is deemed normally unacceptable without review and sound attenuation by HUD (HUD, 1985). Table V-3 illustrates the noise reduction levels (NRL) possible for specific construction materials.

(4) Noise masking is a "cosmetic" relief measure which uses homogenous background noise to dull the perception of intruding noise. It is typically employed in public areas or working environments, and is most effective when the noise intrusion is within 10 db of the background noise (DOD, 1978). It is also possible to allow slight encroachment of external noise to actually improve a working environment where indoor noise has become dominant. The combined noise levels should not exceed basic activity levels. The "masking" or interference of one sound with the perception of another can impact perceived loudness and annoyance. Bienvenue (1986) provides a discussion of the masking of discrete tones.

### Active Noise Control

An emergent technology in the field of noise reduction is called active noise control. Active noise control reduces noise at the source and is characterized by Eghtesadi and Chaplin (1987) as being poised to enter the market place in a variety of major industries. Active noise control is defined by Warnaka (1987) as

a technique by which transducers produce an out-of-phase signal which mixes with an unwanted noise resulting in destructive interference, or cancellation of both signals.

If the phase and amplitude of both waves are closely matched, a high degree of attenuation (e.g. 20 dB) can be achieved. The cancellation wave must be 180° out of phase with the signal wave.

Active noise control allows noise and vibration to be effectively canceled through two basic approaches (Eghtesadi and Chaplin 1987). The first involves processing the original sound and injecting it back into the sound field in antiphase. The second involves synthesizing the canceling waveform and emitting it into the sound field.

Possible areas of future application include jet and turbomachinery noise, helicopter rotor noise, exhaust and air intake noise, fan and blower noise, and many repetitive fixed-facility noises. An active noise control system is presently best suited for handling repetitive sources of noise. Many applications remain economically infeasible. The power for an antinoise sound must often be equivalent to the power needed for the noise source. New advances in loudspeaker technology offer the promise of reduced implementation costs (Eghtesadi and Chaplin, 1987).

TABLE V-3  
TYPICAL BUILDING CONSTRUCTION NOISE LEVEL  
REDUCTION VALUES

Type of Construction	NLR in dB
	Aircraft and Vehicular Noise
Conventional wood frame - windows open	15 - 20
Conventional wood frame - windows closed	25 - 30
Conventional wood frame - no windows or 1/4" glass windows, sealed in place	30 - 35
1/8" glass windows, sealed in place*	20 - 25
1/4" glass windows, sealed in place*	25 - 30
Walls and roof - weighing 20 to 40 lbs/sq ft, no windows*	35 - 40
Walls and roof - weighing 40 to 80 lbs/sq ft, no windows*	40 - 45
Heavy walls and roof - weighing over 80 lbs/sq ft, no windows*	45 - 50

\*Assuming a surface area consisting of only this element.

Source: DOD, 1978

The widespread application of active noise control remains only a possibility. However, as with other possibilities for technological change, it should be closely watched. The planning process in a noise management program should include due consideration for technological change.

### **Operational Measures**

Within the category of physical measures, attention will now be shifted from technological to operational measures. As opposed to technological measures, they do not necessarily involve a reduction in noise levels but a change in impact on the receiver. A large number of techniques are available for the primary noise sources in the military. In considering any type of operational measure, the principal concern is the preservation of the military mission. Although a particular technique may be well suited to noise abatement, unrealistic training situations that significantly alter the performance of equipment, as a result of its use, may require the consideration of other alternatives. The following discussion describes some of the operational alternatives available for noise abatement for specific noise sources.

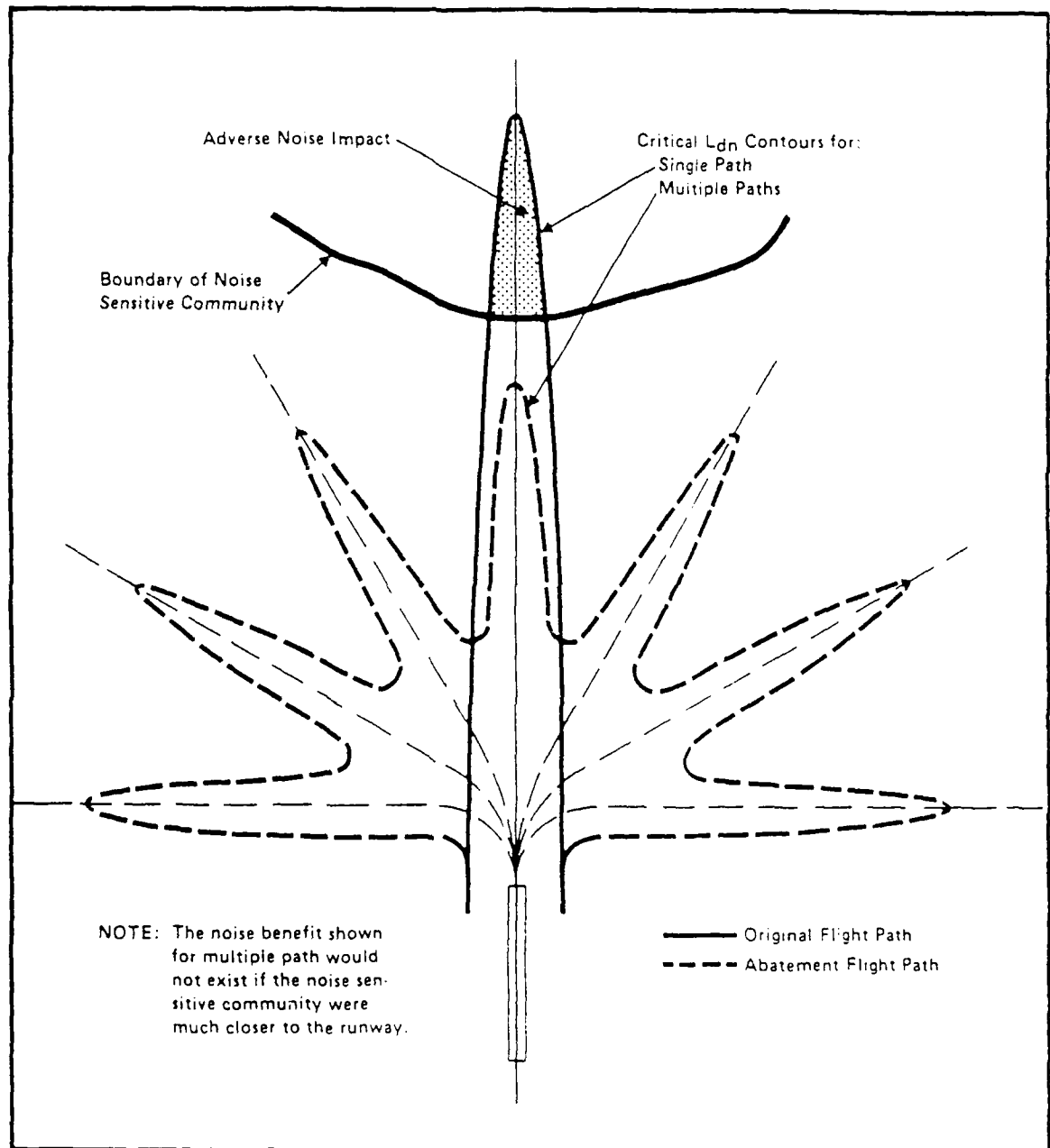
#### **Fixed-Wing Aircraft**

Operational noise control actions must consider air traffic control procedures, mission capability, and safety. Techniques for noise control can be affected by aircraft type, payload, runway length, approach, takeoff patterns, etc. The general measures that follow are a basic list of items applicable to military aircraft and are a modification of several sources (DOD, 1978; Cline, 1986, and Bragdon, 1983).

- (1) Limit night flights. Individuals are more sensitive to night flights when the startle effect is more predominant. This is the reason many noise measures employ an additional decibel penalty for nighttime flights.
- (2) Limit number of operations or distribute operations evenly over time. Often a total allowable noise exposure limit can be established in cooperation with the community and flights limited to this amount. Flights should also be distributed as evenly as possible over a given time period. This will avoid large peaks in operations which could result in excess noise exposure for that period. Both constraints should consider possible conflicts with mission requirements.
- (3) Use of rotational runways or route dispersion. A rotational runway schedule will limit the time that one specific area is overflowed, but like route dispersion, will increase the area subject to noise and crash potential.

However, the severity of the noise impact will be diminished. Figure V-3 illustrates the effect of route dispersion on noise impacts.

- (4) Review the location and scheduling of ground runups operations. Run-ups of aircraft engines for testing and maintenance can last a few seconds to several minutes. These can be quite annoying to the public especially when tested at night. Location of the engines during run-up can also have an effect on a particular area. Remote locations away from noise sensitive areas should be considered. If unavailable, options such as the use of hush houses may merit consideration.
- (5) Use of training simulators. Training simulators are becoming more and more realistic. Simulators can reduce some flights and thereby reduce total noise exposure.
- (6) Reduced thrust during takeoff. A low power climb greatly reduces the noise impacts that result from takeoffs. However, greater distances are required to obtain an altitude where noise impacts are minimal. This measure will decrease fuel consumption but may affect mission training.
- (7) Maximum climbout angle. The use of a full throttle will allow the aircraft to climb at the steepest angle and in the shortest horizontal distance. The severity of the noise impact near the runway will be increased, but areas downrange will have a lessened impact because of the increased altitudes. Fuel consumption will be increased.
- (8) Flap setting. If the flap angle is reduced after a particular velocity is obtained, a steeper ascension angle and a reduction in thrust are possible. The higher altitude and lower power setting will reduce the noise-impacted area and decrease fuel consumption.
- (9) Power cutback. Power cutbacks over specific noise sensitive locations downrange will decrease noise levels in the area but may increase noise downrange where power is resumed.
- (10) Holding and maneuvering altitudes. Holding and maneuvering patterns at high altitudes can reduce noise levels near the airfield. This will reduce noise levels up to the time of descent.
- (11) Approach glide angle. A maximum practicable increase in the approach glide angle can reduce noise for areas under the runway approach.
- (12) Reverse thrust limits. Limitations on the use of reverse thrust for additional braking power will reduce sideline noise on the runways but will require longer runway usage and therefore increase taxi time.



Source: DOD, 1978.

Figure V-3. The Effects of Route Dispersion on Noise Impacts

- (13) High-speed approach. Aircraft descent at a high speed with reduced thrust will reduce noise levels in outlying areas. This procedure requires additional pilot workload and may be preferred for aircraft with automatic landing gear.
- (14) Delayed flap and gear extension. This will reduce airframe drag and the engine power required. A reduction in noise will occur up to the point of extension.
- (15) Flap setting. This will also reduce airframe drag and reduce engine power needed for a specific speed. Outlying areas will experience a decrease in noise levels and a decrease in fuel consumption will occur.

The previous are a limited list of potential options for noise reduction. Many of these may be impractical for specific military missions. An example is Naval flights which must often practice low-altitude flying to match the precision takeoffs and landings required for aircraft carriers. A requirement for high-altitude flight patterns could impair mission capabilities (Zusman, 1988). The preservations of the mission should be the primary concern for adaptation of any operational measures. Each operational measure carries with it specific costs and benefits which must be weighed against one another. Table V-4 outlines each measure and some of the potential costs and benefits of each.

### **Rotary-Wing Aircraft**

The measures to abate rotary-wing noise are very similar to those for fixed-wing jet aircraft noise. The main distinction is the noise source, which is predominantly the rotor system and engines, instead of jet engine noise with the fixed-wing aircraft. The absolute noise levels are approximately one-half of that generated by jet transports; however, the impulse nature of the rotor system may cause increased annoyance. Fields and Powell (1987) provide a recent discussion of helicopter noise annoyance.

The following noise abatement techniques are those particular to rotary-winged aircraft, with an understanding that many of the measures previously listed for fixed-wing aircraft are also applicable. The following measures are adaptations from DOD (1978) and Helicopter Association International (1983).

TABLE V-4  
POTENTIAL BENEFITS AND COSTS  
OF FIXED-WING AIRCRAFT NOISE ABATEMENT MEASURES

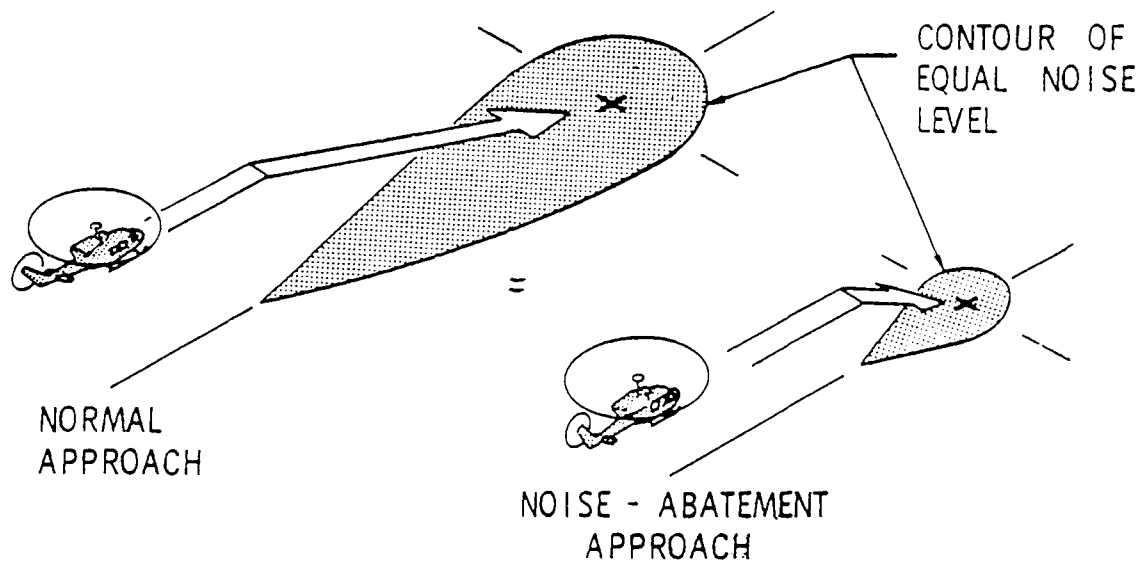
	Procedure	Potential Benefits	Potential Costs*
T	Reduced takeoff thrust	Reduced noise in runway area and close downrange, decreased fuel consumption	Increased noise far downrange
A	Maximum climbout angle	Reduced noise downrange	Increased noise close downrange
K			Increased fuel consumption
E			
O	Flap setting	Decreased noise throughout takeoff, decreased fuel consumption	No direct costs
F	Power cutback	Reduced noise after cutback	Increased noise far downrange
F			
A	Holding and maneuvering patterns	Reduced noise up to descent	No direct costs
P	Approach glide patterns	Reduced noise up to touchdown	Optional automatic guidance system
P	Reverse thrust limits	Reduced noise in runway area	Runway lengthening More taxi time
R			
O	High-speed approach	Reduced noise up to landing field	Automatic landing system
A	Delayed flap gear extension	Reduced noise up to point of extension	Optional automatic extension equipment
C			
H	Flap setting	Reduced noise up to touchdown, reduced fuel consumption	No direct costs
O	Limit night flights	Decreasing nighttime annoyance	Increased noise during day
T	Rotational runways and route dispersion	Decrease of noise exposure in some areas	Increase in exposure to some areas
H	Rescheduling of run-up operations	Decreased noise levels	No direct costs
E			
R	Training simulators	Reduction in all noise areas	Cost of simulator

\* A number of benefits and costs may exist. Cost may include mission impairment, staff time, pilot training, etc.

Source: Adapted from DOD, 1978.



- (1) **Takeoff and approach.** The vertical takeoff and approach capabilities allow for a much greater possibility for reducing noise exposure near the airfield than with fixed-wing aircraft. However, cutbacks in engine power are not possible. Descent rates and airspeeds should be adjusted as to best minimize blade slap. Figure V-4 illustrates the decrease in the ground noise exposure footprint that is due to a steeper angled approach.



Source: Helicopter Association International, 1983.

Figure V-4. Change in Noise Exposure Footprint from Alternative Angle

- (2) **Flight altitudes.** Avoid flying low near hospitals, schools, residential areas, and other highly noise sensitive areas. Altitudes over 2,000 feet are recommended when approaching noise sensitive areas (Helicopter Association International, 1983).
- (3) **Flight patterns.** Adjust flight pattern to maintain noise sensitive areas on the right side of the helicopter. This is the opposite side of the tail rotor. In addition, the noise exposure is lower when the noise sensitive area is kept on the inside of a turn rather than the outside. Avoidance of high G turns in sensitive areas is also recommended.

- (4) Route modifications. Whenever possible, follow major thoroughfares such as highways or railroad beds. Use only routes that are necessary for mission requirements.

This list of measures can be employed along with operation scheduling to avoid excess night flights. Most training missions for rotary-wing aircraft include the use of terrain features or low-level flights. Some of these measures may result in the degradation of the mission and are therefore not viable alternatives. Whenever possible, procedures that produce excess noise should be used only where noise sensitivity is not an issue. The potential costs of the measure described are listed in Table V-5.

TABLE V-5  
POTENTIAL BENEFITS AND COSTS  
OF ROTARY-WING AIRCRAFT NOISE ABATEMENT MEASURES

Procedure	Potential Benefits	Potential Costs*
Takeoff and approach	Reduced noise in all areas	No direct cost Increased pilot workload
Flight altitudes	Reduced noise up to descent	No direct cost
Flight patterns	Reduced noise level in noise sensitive areas	No direct cost Increased pilot workload
Route modification	Reduced noise level in noise sensitive areas	No direct cost

\* A number of benefits and costs may exist. Costs include mission impairment, staff time, pilot training, etc.

Source: Adapted from DOD, 1978.

### Impulse Noise

The abrupt peaking of the sound pressure wave, characteristic of weapon blasts and sonic booms, produces a startling effect which can highly annoy individuals. Technological measures are largely ineffective in this area so operational methods are the predominant means of noise abatement (Schomer, 1988). For sonic booms related to supersonic aircraft operation, policies aimed at reducing noise exposure should be concerned with rerouting and/or increasing flight altitude. Impulse from weapons or demolition have additional measures which are discussed in brief.

- (1) Remote locations. When available, the best method for reducing the impact of weapon noise is through the use of remote training facilities. This option may not always be available for installations in densely populated areas.
- (2) Regulate hours. Scheduling of training that includes blast or impulse noise should be established during less noise sensitive hours. Occasionally the mission may include night training which may require other operational alternatives to reduce noise impacts.
- (3) Restrictions during focusing conditions. Temperature inversions and wind velocity gradients will focus sound waves back toward the ground. Monitoring of atmospheric conditions should be conducted so that training schedules can be modified accordingly (Schomer et al., 1976).
- (4) Use of smaller charge. Optimal elevations on artillery training will allow the use of smaller charges and reduce noise impacts. This may not be desirable in all training situations (Raspet, 1979).
- (5) Selection of explosion sites. Training for demolition or other use of explosives should be performed on soft or swampy areas, which will dampen sound effects, rather than on hard areas such as granite (Goff and Novak, 1977).

### Vehicular Noise

Vehicular noise is considered to be the most pervasive and widespread noise problem in our environment (Bowlby, 1982). Vehicular noise can be divided into street and combat vehicle noise. Street vehicles are operated on paved roadways. Combat vehicles are operated by the military in an off-road environment. Technological measures discussed in the previous section, such as vehicle maintenance and barriers, are commonly used. However, operational

procedures that can be used in combination with barriers can further reduce noise. The following discussion outlines several operational procedures to alleviate the impacts of vehicular noise as adapted from Federal Highway Administration publications and DOD (1978).

- (1) Prohibition of certain vehicles. Heavy vehicles such as large trucks and track vehicles (tanks and personnel carriers) can be excluded from operating in noise sensitive areas.
- (2) Speed and volume reductions. Reduction of speeds or the volume of traffic can reduce noise levels. A typical automobile increasing its speed from 36 mph to 62 mph will result in an increase in noise level from 65 dBA to 74 dBA (FHWA, 1980g). Similar changes in noise levels from increases in speed for medium and heavy trucks are presented in Table V-6. A decrease in traffic volume will decrease the total noise contribution and result in lower noise emissions.
- (3) Traffic controls devices. Moderate and steady freeflow is quieter than stop-and-go traffic (DOD, 1978). Computerized traffic signals and the elimination of unnecessary stops can facilitate the freeflow of traffic.
- (4) Time-use restrictions of certain vehicle types. Prohibition of specific noisy vehicle types during noise sensitive hours can be an effective abatement technique.
- (5) Routing. Established routes around noise sensitive areas. Special routes for heavy and tracked vehicles can be established.
- (6) Operator awareness. Operator sensitivity to vehicle noise levels from inefficient or poorly maintained equipment must be stressed.

### Fixed Noise Sources

Fixed facilities include any stationary noise source, commonly referring to maintenance shops, power plants, and manufacturing plants. Most techniques for noise reductions of fixed noise sources involve the use of barriers, enclosures, or machine design changes. Operational changes can also reduce noise levels or the noise exposure of employees. The following are a few commonly employed operational techniques predominantly modified from Cheremisinoff and Ellerbusch (1982).

TABLE V-6  
RELATIONSHIP OF VEHICLE SPEED TO  
NOISE EMISSION LEVELS

Speed	Noise Level (In Weighted Decibels)		
	Automobile <sup>1</sup>	Light Truck <sup>2</sup>	Heavy Truck <sup>3</sup>
36	65	77	82
42	68	79	84
48	70	81	85
54	72	83	87
62	74	84	88

1. Vehicle two to four wheels less than 10,000 lbs.
2. Vehicle two axles six wheels less than 26,000 lbs.
3. Vehicle three or more axles greater than 26,000 lbs.

Source: Adapted from FHWA, 1980d.

- (1) Equipment relocation. The primary objective is to use distance to reduce noise levels. If the machinery requires little attention, isolation may be usable. The main concern is to locate the equipment so that workers are subjected to the minimal noise exposure possible.
- (2) Equipment replacement. As equipment becomes older it becomes less efficient, more difficult to maintain, and most often noisier. If costs allow, replacement of the equipment with newer and quieter equipment can reduce noise levels.
- (3) Rescheduling work exposure. Rotating workers on a regular basis during the day from areas of high noise exposure to a lower one can keep exposure levels below accepted limits.
- (4) Use of hearing protection devices. In some instances, the only control may be to mandate the use of hearing protection devices such as earplugs or headsets. Education on the health problems of excessive exposure to high noise levels can encourage personnel cooperation.

The previous technological and operational noise mitigation techniques form the basic structure for noise control on military installations. As discussed previously, different mitigation techniques are more applicable to some noise sources than others. Table V-7 taken from Goff and Novak (1977) summarizes the different mitigation techniques available to military installations for specific noise sources.

TABLE V-7  
MITIGATION TECHNIQUE vs. NOISE SOURCE

Mitigation Technique		Noise Source								
Class Type	Artillery /blaste	Pistol range	Rotary wing	Combat vehicle	Private vehical	Fixed wing	Railroad	Construc- tion	Fixed source	Ground run-ups
Design modification	X	X	X	X		X	X	X	X	X
S Retrofitting	X	X	X	X		X		X	X	X
O Maintenance			X	X		X		X	X	
U Simulators	X	X	X	X		X				
R Relocate/reroute	X	X	X	X	X	X	X		X	X
C Reschedule	X	X	X	X	X	X	X		X	X
E Meteorological	X									
Operational	X		X	X	X	X		X	X	X
P										
A										
T Barriers/enclosures	X	X		X	X		X	X	X	X
H										
R										
E										
C										
E										
I Architectural design	X	X	X	X	X	X	X	X	X	X
V Relocate	X	X	X	X	X	X	X	X	X	X
E										
R										

Source: Goff and Novak, 1977.

Although these techniques form the basis for noise control, an organized structure with administrative support is essential for the successful implementation of the techniques. The following sections detail the organizational measures and the public relations and community involvement necessary for a successful noise management program.

## ORGANIZATIONAL MEASURES

Organizational measures are actions directed toward improving the form and function of a noise management program. These actions emphasize the creation of

roles and responsibilities within a noisemaking organization and/or noise management program to best ensure the full consideration of noise impacts.

Organizational measures were a common area of emphasis noted in the interviews with the noise program managers and noise experts. This section is largely based on the comments and "lessons learned" from those interviews and is an attempt to synthesize some of the information gathered in the interview process. It is possible to identify three areas which were recurrent themes in the interviews: (1) the structure of decision making, (2) program support, and (3) program training. The need for open communication within an organization was also commonly mentioned. It can perhaps be thought of as the thread that ties the other three themes together. Each of the three themes will be examined individually.

Many of the past attempts at resolving noise management conflicts have centered on developing physical solutions. Consequently, there is a paucity of documented evidence available on the effectiveness of organizational measures. When implemented, they have usually been done in conjunction with other approaches, such as physical techniques or public relations programs, and measure-specific evaluation is often impossible. Nevertheless, organizational measures can play a crucial role in determining the effectiveness of a noise management program, and their potential contribution should not be underestimated. This section concludes with an example of an organizational action (developing procedures for handling complaints) that can impact the success of a noise management program.

### **Structure of Decision Making**

The structure of the decision-making process can be crucial to success. This includes the structure of the noise management program itself and also its place within a larger organizational system. To clarify, in developing a noise management program, consideration must be given both to roles and responsibilities and to interrelations with other programs.

Several quotes can be used to highlight the importance of this item. Bill Cox (1988), of the U.S. Air Force, is only one of a number of sources to stress the value of a multi-disciplinary team approach involving, for example, planners, air traffic controllers, the legal officer, the public affairs officer, etc. Cox states that

within the Air Force, the AICUZ program is under Civil Engineering and sometimes it never gets out of this corner of the system.

The program implementer has a twofold problem: convincing both on-base and off-base groups of program importance. The requisite skills go beyond just engineering.

Mark Dunning (1988) of IWR reiterates this idea:

Another lesson is the importance of a team approach, but with greater responsibility on the part of the noisemaker. There is a need for change in the current structure. We have got to bring in the idea that, "If you make the noise, you've got to control it."

Within the U.S. Army's Training and Doctrine Command (TRADOC) for example, this would require that actual noisemakers, Training and Testing, be directly participating in the noise management program (ICUZ).

The current decision-making process at O'Hare International Airport in Chicago provides an interesting example to consider. The city is the airport proprietor and thus responsible for noise management. The O'Hare Advisory Committee is composed of a variety of community leaders and has no explicit power or direct responsibility. The committee was created under a court consent decree that was the result of a long litigation battle. The airport has had a difficult time in dealing with the committee whose implicit power is quite strong (Hamill, 1988). The current setup may hinder effective decision making by blurring the lines of responsibility and authority.

Turning to the question of a noise program's place within a larger organizational structure, an important consideration is the need for integration. This integration may take shape in a variety of forms, from noise considerations within an EIS review under NEPA to the assessment of noise compatibility within a local land use planning process.

John Singley (1988), sociologist for the IWR, discusses the need for integration with respect to the Army ICUZ program. The program may have an initial cluster of resource needs in the early stages of implementation. But once that initial hump is negotiated, then the costs may even out. Singley states that

there are certain routines pertaining to the flow of information that can be followed. The program is then made part of the circuitry and costs can be reduced. Planning (which is future oriented) has to be integrated with management (the day to day operations). The program must become part of the SOP - Standard Operating Procedure. In other words, the goal is to blend noise issues into the current set of activities and the current structure of the organization.

The program developed should also be funded commensurate with the level of real or potential problems. Rather than pursuing ad hoc or crisis management, there is a need to gauge the program requirements and then integrate it into the existing structure.



The experiences of a base planner with the Air Force AICUZ program serve as a useful illustration of successful integration. Geno Patriacha (1988), of Davis-Monthan AFB near Tucson, has achieved success in encouraging noise compatibility in local land use planning by emphasizing the safety aspects of the AICUZ program. While both safety and noise are interrelated, a greater degree of success was achieved when the program was targeted to the safety issue. People seemed to relate better to the safety message. This was especially true when dealing with individuals (contact points in the community) who did not themselves live within the noise contours.

### **Program Support**

Success or the ability to achieve objectives in a noise management program is dependent on the support given to the program. For a military noise program, this means the amount of priority placed on the program within the chain of command. As Tim Knapp (1988), base planner at Bergstrom AFB, states:

You have to have senior leadership behind you. You have to go to them and sell the program, and make sure they understand it. In the Air Force, this includes the Civil Engineer, the Wing Commander, the Unit Commander, and finally, the Base Commander.

Command support may also play a role in an installation's relationship with local communities. If the reply to a local request for comments on a development proposal comes from the base commander, then the credibility of the message may be increased.

An interesting parallel can be drawn for a nonmilitary noise program. In the 1970s, noise management was a banner issue and the EPA played a primary role (which included coordinating federal efforts). In the late 1970s, the noise program in the EPA had a staff of over 100 and a budget of well over \$10 million (EPA, 1979). In 1982, the Reagan administration's Office of Management and Budget (OMB) disbanded the EPA's Office of Noise Abatement and Control (ONAC). Today, EPA activity in noise management is minimal. The lack of administrative support was certainly a key factor in this dramatic change.

The U.S. Navy has a very centralized structure to the AICUZ program (Zusman, 1988). Responsibility for program implementation is not left with the individual installations. However, base support for the programs is strong. The AICUZ program has been in place with the Navy for over 15 years and in a sense has become "institutionalized." Dealing with noise management issues is also an integral part of the Officers Training Program. Thus, the structure of the program influences future

support for noise management within the chain of command (Zusman 1988). If the officers have an awareness of the issues, then the system may begin to have built-in support for noise management. This ties together not only the previous lesson but also the next one: the importance of training.

### **Program Training**

A common item identified in the interviews was the importance of staff and personnel training. The breadth of the noise management arena often requires that a program implementer deal with a variety of technical, legal, political, and socioeconomic factors. High personnel turnover can exacerbate the difficulty in keeping a staff adequately trained. As Robert Armstrong (1988) of the FHWA notes:

A lot of the tools are in place and have been in place for several years to deal with the technical aspects. Due to the large turnover of staffs, training and education is a never ending battle. The technical aspects can be explained in a manual but the policy aspects have to be personally explained . . .

Training first requires that personnel be sensitized to the real or potential impacts of noise. Once recognition of the problem is gained, then the technical and conceptual tools to deal with the problem must be provided. Finally, the funding and resources available to develop solutions must be identified.

### **An Example: Developing Procedures for Handling Complaints**

Establishing specific procedures for handling complaints provides an example of the importance of organizational measures to improving noise management. The focus here is on the roles and responsibilities within the organization. Handling complaints is one of the most sensitive areas of interaction with the public, however, it is believed that actions directed within the organization or management program will also play a key role in determining effectiveness. The development of standard operating procedures for handling complaints ensures that the public will not receive mixed signals and that the maximum amount of useful information is gathered.

The following is a set of procedures established for recording noise complaints at Army Installations (U.S. Army Training and Doctrine Command, 1982). The procedures are implemented using a standardized complaint questionnaire and follow-up form.

- (1) Complaints are received by the Public Affairs Officer (PAO) who is responsible for ensuring that the complainant is aware of the installation's mission and that every effort will be made to correct the problem, mission permitting.

- (2) The PAO routes the complaint to the office having responsibility for the type of activity that created the noise complaint. The PAO requires a response for the purpose of providing information to the complainant.
- (3) A copy of the complaint is furnished by the PAO to the Directorate of Engineering and Housing (DEH). The DEH has overall responsibility for the environmental program and can provide technical assistance to both the PAO and the noisemaking activity.
- (4) The noisemaking activity completes a follow-up by identifying the cause of the noise and any actions taken to correct the problem. If action is inappropriate then this will be documented. A copy of the follow-up is provided to both the PAO and the DEH.

It is evident that effectively dealing with noise complaints requires communication and coordination among all involved offices/activities within the organization. The above procedure also allows a noise complaint log to be kept. The log serves as a useful source of information on trends and past experiences. The documentation of why corrective actions are not taken, such as to protect mission capabilities, can also serve to protect the Army's legal position. Rouse (1986) provides an invaluable discussion on developing a complaint response system for handling overflight and artillery-firing claims. Luz, Raspet and Schomer, (1985) also note that the time pattern of complaints suggests the importance of effective response to first-time complaints. Standardizing complaint response procedures is a small but important example of an organizational action that can aid in the solution of noise management problems.

### **Summary**

The development of a successful noise management program requires that an effective decision-making process be implemented. Roles and responsibilities within the program, and the program's place within the larger organization, must be delineated. Achieving program objectives is often dependent on staff training and administrative support. It is critical that open communication be maintained throughout the organization. Developing standard operating procedures for handling noise complaints is an example of an organizational action that can affect the success of a noise management program.

### **PUBLIC RELATIONS/INTERACTION MEASURES**

This section identifies and describes activities undertaken by an organization or noise management program to promote a favorable relationship with the public.

A brief introductory discussion further defines public relations/interaction measures and establishes their potential importance as part of a larger noise management program. This will be followed by a listing and summarization of advantages and disadvantages for some of the available techniques. Finally, a more detailed description will be given of some of the more prominent public relations/interaction programs (AICUZ, ICUZ, and FAR Part 150 studies). These activities can manifest themselves in a variety of ways and are referred to by a number of titles. Public Relations, Public Education, Public Involvement, Public Participation, and Community Involvement are some of the more frequent names given these types of activities. The fundamental distinction among these activities is in the direction of the flow of information. When the flow of information is directed one way from an organization to the public as a means of educating and informing them, it will be referred to as public education or public relations. When the action promotes feedback from the public through a variety of channels, this two-way flow of information is referred to as public interaction. Any given public relations/interaction activity can also be characterized by whether it is a discrete event or part of a larger ongoing process or program. Grisham (1988) states:

When well planned, public information efforts can significantly help an agency establish its credibility, prove the legitimacy of its actions, and gain the respect of the public, all of which are necessary ingredients to the continued and effective existence of a governmental organization.

Failure to involve or inform that public at worst can result in litigation against military installations. The fact that litigation has occurred in the past proves how serious noise issues can be to the public (Singley, 1986).

According to Creighton (1983), public involvement hopes to accomplish four major objectives.

- (1) Conflict resolution
- (2) Legitimizing the decision-making process
- (3) Informing the public
- (4) Improving the decision

Conflict resolution attempts to resolve the problem before litigation occurs. Many conflicts between two parties, such as a military installation and the community, can be solved through collaborative problem solving. Dunning (1986) states:

Collaborative problem solving processes are aimed at facilitating the ability of groups in conflict to work together to develop solutions to their disputes which satisfy the interests and needs of the disputants.

The use of a facilitator to help the two groups resolve their differences as smoothly as possible is an integral part of collaborative problem solving or any type of conflict resolution. A detailed discussion on this topic is provided by Dunning (1986), Collaborative Problem Solving for Installation Planning and Decision Making.

Besides resolving possible conflicts, public relations and interaction measures legitimize the planning process. By involving the public, the decision may be perceived as fair and legitimate. Special interest groups may not approve but as long as the larger public is satisfied, credibility can be established. As stated by Singley (1986), "visibility breeds credibility." Simply informing the public is a valuable tool. It will allow citizens to understand how the process works, and any disagreements are more likely to come from an informed base (Creighton, 1983). A committed public involvement program will take into consideration informed complaints.

Finally, public relations or interaction programs can vastly improve the decision-making process, the implementation of the program and provide the basis for resolving future problems. According to Singley (1983), when the public genuinely participates in the decision-making process they are far more committed to implementation of any plans. Their input may also reveal options unknown to the installation planners and provide data otherwise unavailable. Establishing good relations increases problem-solving capabilities.

The interviews with noise managers reinforced these concepts. Public relations and public interaction were priority concerns for many managers. Bob Cole (1988) of the U.S. Army's Fly Neighborly Program stated that "success is based on telling people exactly what is going on; giving them information." In addition to the dissemination of information, the managers concerns about integrating the public input were voiced by the Airport Noise Officer of Stapleton International Airport (Denver), Steve Alverson. He stated, "To be effective, you must listen to and understand all sides of the noise issue and let them (the public) know that everything possible is being done to correct the situation" (Alverson, 1988).

Another critical element is the promotion of good will and understanding between the noise producer or regulator and the affected public. Bob Armstrong (1988) of the Federal Highway Administration seemed particularly aware of this issue when he stated:

Besides communication within the FHWA, communication or public relations with the community is essential. States need to present a feeling of good will, and respect the needs and desires of the public.

This element of the public relations/interaction program, the development of good will, may be the most important single factor in reducing or preventing conflict.

Duffy (1986) addressed this very topic when he stated:

How can you reduce noise level by going to an evening meeting in a high school cafeteria? The straight forward answer is: "You can't." The real answer is that if you show genuine concern and demonstrate that you are trying very hard to improve a situation; people will try to help you. Their part of the process is often to be patient and let you try, hoping that both parties will benefit. What is happening of course, is that the negative community reaction associated with a given  $L_{dn}$  (noise) level is reduced, for a given area for a given time, to the reaction usually associated with a much lower level.

An excellent example of a public relations/interaction activity which has attempted to improve its relationship with members of the community is the Helicopter Association International's Fly Neighborly Program. The Fly Neighborly Program is a voluntary noise reduction program which is designed for use by all types of civil, military, and government helicopter operators (Helicopter International Association, 1983). The objectives of the Fly Neighborly Program are achieved through a plan consisting of three elements. They are (1) pilot training and indoctrination, (2) flight operations planning, and (3) public awareness promotion. The third element, public awareness promotion, consists of increasing public acceptance and developing a heightened sensitivity within the community. The focus is primarily on the dissemination of information about helicopters. The scope also includes promoting media support, campaigns for complaint prevention/resolution, and joint programs with national planning and municipal organizations. An integral part of the educational element is the promotion of helicopters as an alternative means of transportation, thus cultivating a better relationship with the public in general.

A wide variety of techniques are available to develop public relation/interaction programs. The selection of a particular activity or combination of activities should be guided by the goals of the agency and by the concerns of the community. Some of the activities lend themselves to use in a large group, while others require close work among a few people; some require a facilitator or mediator and others do not. The nature of the issue, the number of potentially affected publics, the relationship between the agency and community, and the financial and technical resources available all must be considered when selecting a public relations/interaction technique. Some of the available techniques and their advantages and limitations will be listed and discussed in the following section. This information was taken directly or adapted from the ICUZ Community Involvement Manual (Creighton, n.d.).

## **Public Meeting Techniques**

### **Public Hearings**

**Discussion:** These meetings are formal and include a hearing officer, advance public notice, and a verbatim public record. Participants make formal public statements sometimes accompanied by written submission.

**Advantages:** The formal requirement of public notice will draw a large crowd and a wider variety of input can be obtained. Also the public record allows for later scrutiny of the meeting.

**Limitations:** Partially because of the large crowd and lack of interaction among participants, interest groups may be more likely to make stronger, more emotional appeals than would occur in a small group setting.

### **Large Group Format**

**Discussion:** Even with a large group there exists the possibility of permitting some interaction. A public meeting can be less formal than a hearing and this allows impromptu comments.

**Advantages:** This format allows a freer exchange of information and allows more people to talk than does a public hearing.

**Limitations:** A skilled meeting leader must be present to call on those wishing to speak and to avoid confusion among the participants.

### **Large Group/Small Group**

**Discussion:** This technique should be adapted to the large group format. It involves separating the large group into smaller groups to allow for intensive discussion.

### **Other Public Meeting Techniques**

**Discussion:** A panel format allows the public to question a panel of preselected experts of different viewpoints. This panel may also be questioned by reporters, which may help to specify issues and to communicate ideas to the public. Workshops are often used when a specific task or goal has been set. The participants in the workshop may help to identify alternatives or to identify economic, environmental, and social impacts which may occur.

## Nonmeeting Techniques

### Citizens' Committee

Discussion: The establishment of a citizens' committee may be helpful in a variety of ways: as a "sounding board" for the agency to test its ideas on; in an advisory or monitoring capacity; or as a channel of communication to the public.

Advantages: The citizens' committee allows interested citizens to become involved in the decision-making process. It also promotes trust between the agency and the public.

Limitations: The citizens' committee may come to be viewed as the only public, and the agency may fail to continue relations with other groups. Another concern is that the committee will simply reinforce negative feelings that already exist in the community.

### Interviews

Discussion: Interviews with the public may be used when trying to infer how the majority of the public feels about a particular issue.

Advantages: Interviews allow the exploration of a topic in depth by allowing respondents to discuss the reasons for their preferences.

Limitations: Interviews require large amounts of time and consequently must be limited to a relatively small number of people. The value of the information is largely dependent upon the skills of the interviewer.

The public relations/interaction techniques discussed thus far are those which have been traditionally used among government agencies. Because this is a relatively new field, there are many new, innovative techniques being developed. The following techniques represent some of these new adaptations.

## Other Public Involvement Techniques

### Paid Advertising

Discussion: May be used to announce public meetings, present studies involving public concerns and alternatives being considered.

Advantages: Provides better control of information as opposed to free publicity through the media, which may slant the story. Reaches a broad range of publics and may include questionnaires to solicit public response rather than just inform.



**Limitations:** May be perceived as wasteful use of tax money. Potential disadvantageous effect on the image of the agency if "hard-sell" advertising is interpreted by the community as lacking objectivity or candor.

### **Computer Based**

**Discussion:** Computer can display various impacts, such as existing noise contours on a map, and can show how they will change as a result of mitigation measures.

**Advantages:** Visual demonstrations can provide a good basis for community understanding of present situation and results of alternatives. Offers a convenient form of comparing alternatives.

**Limitations:** Time and expense of such a program may be high. Also, use of the graphics in a public meeting is limited to those who can sit close enough to see. Subject to technical breakdown.

### **Field Offices**

**Discussion:** Local offices established in the community and staffed with knowledgeable personnel allow distribution of "hand-outs" and provide a place for meetings, etc.

**Advantages:** Provide informal interaction with the public. Staff will understand and appreciate the needs and desires of the community.

**Limitations:** May be costly to operate and staff. The field office staff may develop divided loyalties between the agency and the community.

### **Hotline**

**Discussion:** This is an "easy-to-remember," usually toll-free phone number which the public may call to get information or to voice concern on a particular topic.

**Advantages:** A convenient mechanism for community involvement, it can also be used to inform interested persons of meetings or other public involvement activities. Communicates the agency's interest in the comments or questions of the public.

**Limitations:** May involve a major commitment of staff time when manned. Requires coordination with some other community activity to effectively reach the public.

### **Newspaper Inserts**

**Discussion:** Inserts in local newspapers can give information regarding the study or the decision-making process. They often include a response form.

**Advantages:** Newspapers reach a large percentage of the public, and through selectively distributing those papers to certain geographical areas, a specific public may be targeted.

**Limitations:** Relatively expensive with a fairly low response rate. Because respondents are self-selecting, a statistical bias is introduced thus negating any statistical evaluation.

### **Reports, Brochures, or Newsletters**

**Discussion:** These publications vary slightly in form and content; however, their goal is to inform the public of opportunities for participation, progress of the study, and decisions that have been made.

**Advantages:** Direct means of providing substantial amounts of information to a large number of people. They also serve as a permanent record.

**Limitations:** Publications must be visually attractive to be read and consequently may have to be purchased from outside the agency. Information reaches only those who take the time to read the publication.

### **Surveys or Polls**

**Discussion:** Surveys are usually done by phone, mail, or personal interview, and they employ a strict methodology in order to ensure a representative sample of the public opinion.

**Advantages:** They give an accurate expression of the attitude of the public and will indicate whether the participants in the public involvement program are representative of the active community.

**Limitations:** Surveys must be designed so as to maintain the statistical integrity of the data, and this may be costly. Most federal agencies must receive OMB approval and surveys provide no chance for education or discussion of differences.

### **Participatory Television**

**Discussion:** A television program which describes alternative courses of action in a study or issue can reach a large number of people and permits response by mail.

**Advantages:** This option may reach the largest number of people and is very

convenient. Also, even if viewers chose not to participate, they would still receive the intended message.

Limitations: Owing to the high cost of commercial TV, reliance on educational or cable TV may result in a small, nonrepresentative viewing public, and no special concern is given those most affected, i.e. those in close proximity to the problem.

### **Cumulative Brochure**

Discussion: This will keep a cumulative record of public meetings, workshops, etc., which will document the process from start to finish.

Advantages: This process is highly visible and encourages participation. The inclusion of comments made by the public helps to identify issues of concern.

Limitations: The final brochure is large and it may be expensive to produce in large quantity. Its effectiveness depends on its clarity and its acceptance by the public as an accurate documentation.

### **Mediation**

Discussion: Mediation is a formal but voluntary bargaining process in which a panel is established representing all of the affected parties. An objective "third party" is employed to structure deliberations and to serve as a facilitator for negotiations.

Advantages: Mediation can result in an agreement which is supported by all those involved. It can also speed up the process of resolution without litigation or some other appeal process.

Limitations: Because mediation is voluntary, all of the parties involved must be willing to negotiate. The mediator must be highly skilled and be perceived as completely objective. It may be seen by the agency as a usurpation of regulatory power.

### **Delphi**

Discussion: The Delphi program is a method for obtaining consensus on forecasts by a group of experts. A recommendation can be made that may be more appropriate for all of the involved parties.

Advantages: An expert consensus is valuable for making decisions and for lending a sense of legitimacy to those decisions in the eyes of the public.

Limitations: The public may be unwilling to accept the findings of the experts, and the Delphi may tend to homogenize points of view. The process of arriving at the consensus may also be time-consuming.

### **Technical Assistance to Citizens**

**Discussion:** Some agencies have found that providing technical expertise to the community for use in developing their points of view has benefitted both sides of the issue.

**Advantages:** Reduces chance of the public feeling intimidated by the experts from the agency. Ideas from the public can be developed into more viable options.

**Limitations:** It is difficult to supply technical staff to all interested parties. The public may not trust the staff, depending on the relationship between the community and the agency.

### **Training Programs for Citizens**

**Discussion:** Training programs are conducted to improve citizens understanding in the following areas: (1) planning and decision making, (2) substantive content, i.e. environmental impact assessments, and (3) meeting leadership.

**Advantages:** This kind of training may increase the effectiveness of the public participation and improve the contributions made by the public.

**Limitations:** Citizens may be hesitant to accept "training," and those who do may be nonrepresentative of the whole public.

The above listing and discussion have presented some of the major techniques available for public relations/interaction. Commonly, a number of techniques will be combined and integrated into the larger noise management program. At this point, several programs which emphasize a public relations/interaction approach will be examined in greater detail. Specifically, the Department of Defense's AICUZ and ICUZ programs and the Federal Aviation Administration's FAR Part 150 program will be reviewed.

### **FAR Part 150 Studies**

Federal Aviation Regulations (FAR) Part 150 implements portions of the Aviation Safety and Noise Abatement Act of 1979 and among other things establishes a standardized noise compatibility planning program. A Part 150 study is a voluntary process designed to achieve cooperative efforts in addressing noise/land use issues. The basic objective is to

develop a balanced and cost-effective program to minimize and or mitigate the airport's noise impact on local communities (FAA, 1983).

The study process represents an interactive approach to problem solving. A forum is created for including all the affected parties in the decision-making process. This group

includes the airport proprietor, state and local planners, local aviation groups, and interested citizens (FAA, 1983).

Federal financial assistance is available for planning and program implementation. Eligibility for assistance requires that a final approved Part 150 plan be filed with the FAA. Up to 90 percent of the program costs can be paid using money from a federal trust fund. Taxes on airline tickets and cargo and fuel receipts are the source of the fund. However, the total federal assistance available only amounts to \$347 million, and the full costs of implementing a noise mitigation plan at any major airport can easily exceed \$100 million. This may explain why the usage of Part 150 plans has been limited. By mid-1986, only 18 complete plans had been submitted to the FAA for approval (Knack and Schwab, 1986).

A variety of recent developments may point to increased use of noise compatibility planning and programming under FAR Part 150. Noise is considered by the FAA as one of the greatest threats to aviation and the projection of a large growth in demand for air travel. The cost of many mitigation measures such as soundproofing and land purchases are increasing rapidly. The opportunities for individuals to voluntarily move away from airport noise is decreasing. In addition, public perception of acceptable urban noise may be changing. All of these reasons are cited by the FAA (1983) as combining to exert strong pressure on airport operators to implement system-constraining measures such as curfews and growth constraints. Within this context, the need for noise compatible planning and development has been increasingly emphasized.

The Part 150 program is promoted as a vehicle for ensuring noise compatible land use. The FAA (1983) identified the following objectives the program was designed to meet:

- (1) A balanced approach to achieving both aviation and nonaviation interests
- (2) Technical guidance from the FAA
- (3) Consultants and interactions among all affected parties designed to achieve broad-based support for mitigation measures
- (4) Federal financial assistance to both airport operators and local land use jurisdictions
- (5) A viable decision-making framework for evaluating the full costs and benefits of alternatives
- (6) Protective sanctions (under Section 107 of the ANSA Act of 1979) for airport operators from landowner noise suits

In the ideal, the full range of possible solutions to real or potential conflicts is explored, and then the optimal combination of mitigation measures for the specific situation are selected. Table V-8 presents the FAA 17-point "checklist" for noise compatibility programs. The checklist represents the minimum process requirements

TABLE V-8

## CHECKLIST FOR NOISE COMPATIBILITY PROGRAMS

- 
1. Current FAA-accepted noise exposure map included.
  2. Consultations with public and/or planning agencies within L<sub>50</sub> 65.
  3. Consultations with air carriers and other airport users.
  4. Opportunity afforded public to submit views, data, and comments.
  5. Description (summary) of the consultations conducted.
  6. Alternatives considered and presented according to these categories:
    - a. Those within airport operator's implementation authority
    - b. Those within authority of another local agency or state/local governing body
    - c. Those under federal authority
  7. At a minimum have these alternatives been considered:
    - a. Preferential runway system
    - b. Restrictions on use of airport based on noise:
      - (1) Restrictions on aircraft not meeting FAA noise standard
      - (2) Capacity limitations based on relative noisiness
      - (3) Required use of noise abatement takeoff/approach procedures
      - (4) Landing fees based on noise or on time of arrival
      - (5) Other actions recommended for FAA analysis
    - c. Noise barriers and/or acoustical shielding
    - d. Soundproofing of public buildings
    - e. Modified flight procedures and/or flight tracks
    - f. Land purchases, air rights, easements, and/or development rights
    - g. Other actions or combinations of actions having beneficial impact on noise
  8. Description of alternatives considered and the reasons why any alternatives were rejected.
  9. Specific alternative program measures (actions) proposed along with the relative contribution of each to program effectiveness.
  10. Statement of the actual or anticipated effect of the program on reducing noise to individuals and noncompatible uses.
  11. Documentation of feasibility of each proposed measure, including:
    - a. Essential governmental actions
    - b. Anticipated funding sources
  12. Relationship of proposals to existing FAA-approved airport layout plan, master plan, and system plan.
  13. Summary of the comments and materials received via public comment and disposition.
  14. Time period covered by the program.
  15. Schedule for implementation of the program.
  16. Persons responsible for implementation of each program measure.
  17. Schedule for periodic review and updating.
- 

Source: FAA, 1983.

to be covered in an FAA approved Part 150 plan. The airport proprietor is responsible for developing the plan. Emphasis is placed on public involvement, consultations with all affected parties, and a full assessment of the total costs and benefits for feasible alternatives. The process does not always follow the ideal, and there are examples of both success and failure. A look at an example of a Part 150 study may provide a more detailed understanding of the process.

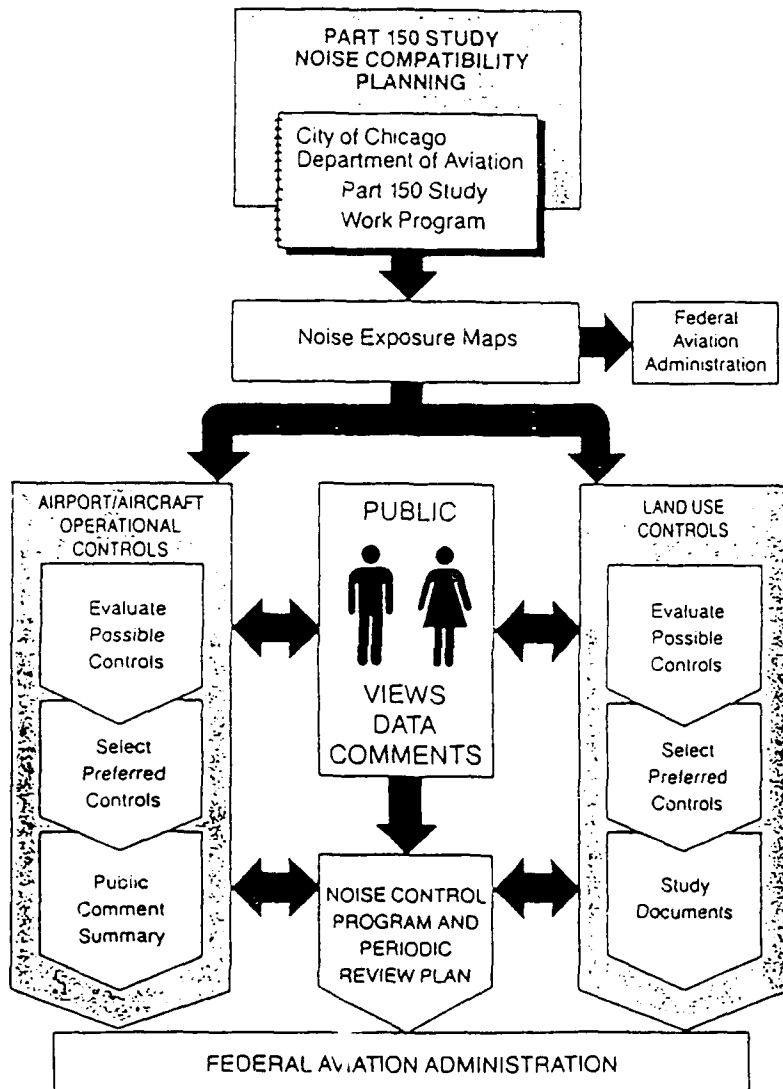
### **An Example: The Chicago O'Hare International Airport Part 150 Study**

The Chicago O'Hare International Airport handles more passengers than any airport in the world. The airport handled over 795,000 operations in 1986, as opposed to 735,000 in 1979. Within the 65 L<sub>dn</sub> and greater sound level contour, there were 93,960 housing units, and a residential population of 281,660 in 1986. There were also 99 schools and 106 parks/forest preserves impacted. These impact figures have all been reduced slightly since 1979 despite the increasing number of operations. Noise remains a very controversial issue at O'Hare. Over 15,000 phone complaints are received per year (Hamill, 1988). The airport and its noise problem have also been the center of a number of legal and political battles. A Part 150 study process has recently been initiated at O'Hare.

Although not specifically required under Federal Aviation Regulations, a set of goals and objectives have been established for targeting the Part 150 study process to key issues. The overall aim of the study was identified as developing a balanced and cost-effective program for minimizing the airport's noise impact on local communities. Increasing public awareness and maximizing public participation in the planning process are also key objectives of the study process (Chicago, O'Hare, 1988).

Figure V-5 represents the flow of work developed for the Chicago O'Hare Part 150 study. The process begins with the preparation of a plan of work and concludes with submittal of a finished noise control program to FAA. The public plays a central role in the process of considering alternatives. Table V-9 lists the actual noise mitigation alternatives which are being considered. This list is primarily useful in identifying the tremendous range of measures which can be implemented in a large-scale noise mitigation program and the degree of difficulty involved in the process of evaluating alternatives.

A variety of political factors have implications for the Part 150 study and noise management in general at O'Hare. As Pavlicek (1982) has noted, the relationship between state authority and municipal airport proprietors is complex. Based on an interpretation of case law, it can be argued that a municipality that operates an airport (as Chicago does with O'Hare) can have their "proprietary prerogatives influenced" by the governing state. Through a proposal issued by the Illinois attorney general, the



Source: Chicago O'Hare International Airport Noise Abatement Office, n.d.

Figure V-5. FAR Part 150 Study Planning Process



TABLE V-9

## THE CHICAGO O'HARE INTERNATIONAL AIRPORT PART 150 STUDY

Actions Suggested For Study	
1.	Accelerate Purchase of Quieter Aircraft
2.	Sell Bonds for Airlines to Acquire Stage 3 Aircraft
3.	Develop Aircraft Mufflers
4.	Ban Airport Expansion
5.	Ban New Runways
6.	Build a Third Airport
7.	Modify Location of Airport Facilities
8.	Runway Length (Extend and/or Displace)
9.	Runway Locations
10.	Build Run-up Suppressors/Hush House
11.	Berms/Barriers for Run-ups
12.	Ban Run-ups
13.	Limit Ground Run-ups
14.	Limit Nighttime Ground Movements
15.	Ban Operations 2200-0700
16.	Ban Operations 2230-0700
17.	Ban Operations 2300-0600
18.	Ban Noisy Stage 2 Aircraft
19.	Ban Noisy Stage 2 Aircraft at Night
20.	Cap Cumulative Noise Levels
21.	Confine 80 L <sub>50</sub> to Airport Property, Eliminate 75 L <sub>50</sub>
22.	Cap Nighttime Operations
23.	Cap Operations to 1987 and Reschedule
24.	Cap Passengers
25.	Close Midway Due to Interference
26.	Discontinue Flying B-727 Aircraft
27.	Expand Quiet Nighttime Hours
28.	Exempt Stage 3 from All Noise Procedures
29.	Limit Operations 2200-0700
30.	Limit Use of Noisy Aircraft (Stage 2)
31.	Noise Budget
32.	Noise Event Level Restriction and Fine
33.	Reduce Operations
34.	Reduce Operations 5%
35.	Reduce Operations - Send to Other Airports
36.	Require Aircraft to be 80% Full
37.	Require all Stage 3 Aircraft by 1990
38.	Rescheduling Traffic
39.	Power and Flap Management
40.	Modify Approach and Departure Profile
41.	Increase Arrival Altitude
42.	Glide Slope Angle and Intercept Distance
43.	Balance Outlying Impact with Close-in
44.	Climb at a Rate of at Least 1,000 ft per Mile
45.	Increase Departure Altitude
46.	Limited Use of Reverse Thrust
47.	Arrival Tracks Follow Roadways
48.	Arrival VFR Corridors at Night
49.	Departures - Fan Tracks/Equalize Tracks
50.	Departures - Straight Until 10,000 ft
51.	Determine Optimal Tracks and Use
52.	Track Restrictions by Aircraft Type
53.	Track Restrictions by Time of Day
54.	Fly Along Roadways (Arrival and Departure)
55.	Fly Over Compatible Uses (Arrival and Departure)
56.	Equalize Runway Use
57.	Concentrate Noise through Runway Use
58.	Runway Use by Aircraft Type

TABLE V-9

THE CHICAGO O'HARE INTERNATIONAL AIRPORT PART 150 STUDY  
(continued)

Actions Suggested for Study	
59.	Runway Use by Time of Day
60.	Rotate Runways: Day, Concentrate: Night
61.	Equalize Night Noise Based on Operations
62.	Increase Funds for Soundproofing
63.	Purchase Assurance
64.	Real Property Notices
65.	Soundproof Schools, Homes, and Others
66.	Soundproofing Tax Bill
67.	Tax Abatement
68.	Zoning Changes
69.	Impact Review Process
70.	Aviation Easements
71.	Fee Simple Acquisition
72.	Adopt a State Airport Land Use Ordinance
73.	Building Code Modifications
74.	Subdivision Regulations
75.	Pay People to Live Near the Airport
76.	Take Control of O'Hare from City
77.	Compensation for Impact
78.	Notify Citizens of Changes in Procedures
79.	Change Operations Based on Hotline Calls
80.	Toll-Free Number for Complaints
81.	Additional Phone Lines
82.	Additional Monitoring Units
83.	Actions Mandatory with Fines
84.	Collect \$.50 Per Ticket for Mufflers
85.	Landing Fees based on Noise
86.	Run-up Fees and Fines
87.	Remove Subsidies from Airports - Users Pay all Costs
88.	Monitor Noise Levels during Implement
89.	Noise Alerts and Mitigation Measures
90.	Publicize Noise by Airlines
91.	Permanent Noise Monitoring - SEL Limits
92.	Ground Track and Profile Monitoring
93.	Permanent Noise Monitoring
94.	Develop 60 L <sub>A</sub> Noise Contour
95.	Different Noise Metric - Do Not Average the Noise
96.	Include Windrose in Report
97.	Publish Noise Maps
98.	Update Base Year to 1987 or 1988

Source: Chicago O'Hare International Airport, n.d.

Illinois Pollution Control Board has in the past ambitiously attempted to influence noise abatement measures used at O'Hare (Pavlicek, 1982). Recently, state legislators from suburban Chicago have attempted to shift control of the airport from the city to a regional commission (Knack and Schwab, 1986). The effects of past litigation have ranged from determining the choice of computer model for predicting noise exposure contours to the formation of a community advisory committee which influences and comments on noise mitigation actions. Political and legal factors have also affected the support of the suburbs for the Part 150 study process. It is feared that the publication of an FAA approved Part 150 noise exposure map may lower property values in impacted areas (Knack and Schwab, 1986) or diminish the chances of winning future litigation cases for noise-impacted individuals whose arguments do not conform to the noise contours (Hamill, 1988).

In summary, the Chicago O'Hare example illustrates where a Part 150 study process emphasizing public interaction has been initiated in a large urban setting heavily impacted by airport noise. While the process has been affected by a variety of political factors, it continues to move forward in the consideration of an impressive array of noise mitigation measures.

#### **Department of Defense Compatible Use Zone Programs (AICUZ, ICUZ)**

In response to increasing concern over noise issues, the Department of Defense initiated compatible use zone programs in the early 1970s. Air Installation Compatible Use Zone (AICUZ) and Installation Compatible Use Zone (ICUZ) are the names given to the specific programs used by the services to provide guidance for noise compatible land use management in the communities adjacent to military installations.

Both programs were a response to the rapid land use encroachment around military installations and legislation such as the Noise Control Act of 1972. Although the AICUZ program was initiated in the 1970s, the ICUZ program has only been implemented within the last decade.

The primary objective of both AICUZ and ICUZ is preservation of the mission of the installation and to protect the health and safety of the public. AICUZ is used by the Navy and Air Force who must cope with a substantial amount of aircraft noise, while ICUZ is used by the Army to manage installation noise sources such as artillery, helicopters, etc.

The AICUZ program concentrates on compatible land use in terms of noise and safety. Three zones of accident potential are extended from the runway. The zone of high potential (clear zone), significant (zone I), and measurable (zone II) are overlaid with noise zones on a base map to determine the AICUZ (DOD, 1978). Zones I and II are known as accident potential zones (APZ). The noise zones are referred to as

zones 3, 2, and 1. Zone 3 is at least 75  $L_{dn}$ , zone 2 between 65 and 75  $L_{dn}$ , and zone 1 is below 65  $L_{dn}$ .

ICUZ is similar to AICUZ except that it places less consideration on aircraft safety and determines its zones solely on noise contours. ICUZ also differs in its use of noise descriptors. AICUZ uses the A-weighted day-night average sound level descriptor, ADNL, to develop noise contours. The vibrational nature of impulse noise sources such as artillery, demolitions, and gunfire requires the use of the C-weighted day-night average sound level descriptor, and therefore the ICUZ program uses both the CDNL and ADNL (AR 200-1).

After the compatible use zones are established, each service may approach the community in a somewhat different manner. All consider technical or operational options to reduce impacts that will not interfere with mission capabilities. However, in some cases the policy emphasis has been on land acquisition for property located in the clear zone. While in other cases, especially in the more urbanized areas, there has been a greater reliance on the local communities to enact zoning controls (Singley, 1986). The Army ICUZ program relies heavily on community involvement and the securing of negotiated agreements. However, there is as yet no solid evidence of successful implementation of formal negotiated agreements with local communities.

Both AICUZ and ICUZ attempt to encourage cooperative land use planning with the local communities. According to Bill Cox, AICUZ program manager of the Air Force, because of the limited unilateral power of the Air Force, or other military service, community cooperation is absolutely required.

The reduction of conflict with local communities is a benefit to the community and the military installation. Singley (1986) outlines lessons learned by federal agencies over the years concerning community involvement. They are:

- (1) Community involvement must be an integral part of the decision-making process.
- (2) The entire process must be open and visible.
- (3) When the public feels a sense of genuine participation in the decision-making process, they are far more committed to the implementation of the plan.

The current level of success of the AICUZ, ICUZ programs is not definitive; however, they do provide for community involvement and thereby increase future problem-solving capabilities. An illustrative example of the ICUZ program for Fort Knox, Kentucky, is provided in the following discussion.

### **An Example: The Fort Knox ICUZ Program**

Fort Knox, Kentucky, was the first application of the U.S. Army's Training and Doctrine Command (TRADOC) ICUZ program. A community involvement component was an integral part of the TRADOC-ICUZ approach. The approach emphasizes proactive planning and cooperative efforts to prevent future noise conflicts. Preventing incompatible land use from occurring is seen as a way of protecting installation mission capabilities. Vincent and Knowlton's (1986) In Progress Review provides the primary source for this discussion.

Fort Knox's mission includes providing support for four different training brigades. The installation covers a relatively small area (109,250 acres) and is situated within an extremely rural area. Noise from the installation impacts six small adjacent communities to differing degrees. The four towns to the west of the base have a strong economic dependence on it, and a generally high tolerance for the noise. The two towns to the east are cut off by rugged topography, have little economic dependence on the base, and exhibit a lower degree of tolerance for the noise.

While the current level of conflict is not high, installation mission has been impacted previously. In 1977 a proposed tank firing point was relocated, partially because of noise impacts on a local church (TRADOC, 1982). More importantly, a potential for increasing noise conflicts exists. Fort Knox's small size allows only limited flexibility for accommodating noise-increasing mission changes, and development in the surrounding area is increasing. The ICUZ study was initiated in 1982 in an attempt to prevent future noise conflicts. Noise contours were developed to represent current and future conditions up to the year 2000. The base implemented a number of noise prevention measures, such as reducing conversion plans, from 105mm to 120mm guns, by 90 percent.

Once the contours were developed and compatible use zones identified, the information was presented to city officials and local and regional planning commissions. The goal was to obtain the cooperation of planning commissions to slow or halt growth near installation boundaries to ensure the continued mission of Fort Knox without future conflicts. A memorandum of agreement (MOA), or "written handshake," was developed to formalize agreements between the installation and local communities.

The level of conflict was low and relations with the community were already strong. Public meetings were an alternative but were not pursued, since local officials felt that the public was not sufficiently concerned enough to attend. Overall, the program is difficult to evaluate. However, some of the strengths of the program are increase in communications with the community and the increased sensitivity to noise concerns. The ICUZ program at Fort Knox provides legal support for the future and a mechanism to work with the local community should future problems arise.

## **ADMINISTRATIVE MEASURES**

Administrative measures are those that can be used by military installations, regulatory agencies, or the local municipalities to directly regulate or to solicit a response which will mitigate noise impacts. Considerable overlap can occur between administrative measures and organizational measures. The distinction is in the control aspect of administrative measures. Since the military is often the noise source and, as a government agency, also the regulator, its use of administrative techniques is unique.

Administrative measures consist of two types of controls, direct and indirect. Direct controls consist of measures that directly control the noise problem. Direct regulation, by prohibiting or regulating some action, or the establishment of emission limits or performance standards are examples of direct controls (NRC, 1977).

### **Indirect Controls**

Indirect controls include financial incentives or possibly public awareness programs that attempt to motivate individuals on an economic or social basis. Some examples are property tax incentives, emission charges for producers, and relaxation of municipal regulations (i.e. zoning regulations if acoustic construction is used).

Financial incentives are the primary means for indirect administrative control. Emission charges are one type of incentive. The use of emission charges relies on economic incentives in the form of charges for environmental damages. One method is to issue permits to noise sources which will allow a specified level of noise emission. If this amount is exceeded, a charge sufficient enough to force the noise emitter to consider noise curtailment can be used (Rosenbaum, 1985).

In a report to the U.S. EPA (NRC, 1977), several advantages of an emission charge are outlined. One argument is that emission charges promote economic efficiency. Sources are allowed to reduce noise levels at the lowest cost possible. Those who can abate noise levels the most efficiently will avoid emission charges at the lowest cost.

Another argument is that the program will eventually support itself. Emission charges can be used to support additional monitoring and other costs to further improve the situation. With direct regulation, enforcement and monitoring must continually be government supported.

Several arguments on economic grounds support emission charges. However, in the military, financial-type incentives such as emission charges and tax incentives may not be an option. As the noise source, and also the regulator, it is difficult to apply these concepts. Tax incentives to discourage land use development near the installation must be enacted by the municipality. Even in cases where the military is not the regulatory

agency, financial incentives such as emission charges will only be effective if the installation is forced to face the consequences of increased noise levels. If they pay, only to have funds approved by the government in an amount to offset payment, the measure will prove ineffective (NRC, 1977).

A modification of the emission charge is the use of a noise cap on the noise source(s). In air pollution, this is known as the "bubble concept." Under the policy an imaginary bubble is placed over a firm and they are free to reduce emissions in any manner to meet the targeted levels (Seneca and Taussig, 1984). For noise control this has been used at municipal airports and is referred to as a noise budget. Often an agreement on a maximum level of annual noise emissions is negotiated with the local community, and the proprietor of the airport assigns noise emission levels to each carrier. The Denver Stapleton Airport refers to this as a noise cap for each airline. Airlines exceeding their average daily noise allocation are charged a \$2,000 landing fee. Any money collected for the exceedance of noise levels is used for any ongoing noise mitigation work. All airlines at Denver Stapleton were below their cap in 1987 (Alverson, 1988). Although it is unlikely that a military installation will fine itself for exceeding a predetermined noise cap, litigation can be prevented from local communities and better relations can be developed. Furthermore, a negotiated cap with local communities still allows for considerable leeway for emission requirements. Since individual sources are not prohibited and only the total noise level of the airfield or installation is considered, mission requirements can be modified to meet any established agreements.

### **Direct Controls**

Direct controls are more widely used as a policy instrument for noise control. Often equipment specifications such as a requirement of mufflers on vehicles or the prohibition of certain activities in an area are used. These administrative types of controls that either prohibit an action or require it are similar to operational measures, covered earlier. Considerable overlap can exist, since an operational change can be a result of an administrative control.

Direct controls are considered more practical than indirect ones in many cases. The largest problem with indirect controls is the lack of large-scale monitoring systems which can pinpoint specific noise sources (NRC, 1977). Only in the past few years has monitoring become widely used at municipal airports. Equipment specification and requiring or prohibiting devices or activities, although not necessarily cost-efficient, may be the only reasonable alternatives.

As noted previously, in Chapter IV, regulatory controls and source emission limits have been widely used in the U.S. since the mid-1970s. However, many of the direct land

use controls, especially zoning measures, must be implemented by the local communities. Often military installations have little control concerning zoning around the facility and must rely on the community to prevent incompatible land use. The following chapter examines administrative measures from the aspect of local land use management in greater detail and provides explanations of the numerous options available.



## **VI. LOCAL LAND USE MANAGEMENT**

The objective of this chapter is to examine the available administrative techniques for noise compatible land use management. Land use management is an administrative solution to noise problems that is not directly available to the military (outside of its own land). Noise compatible land use in communities adjacent to installations can only be encouraged or assisted by the military.

Attempts to actively involve local communities in noise compatible land use management have grown in recent years. If a noisemaker (i.e. military installation or airport) is to successfully promote this process, then an adequate knowledge of the available options must be acquired. The particular conditions of any local noise issue will dictate which land use management strategy is optimal. However, understanding the full range of alternatives available and having some general insights on their applicability are prerequisites to effective decision making.

In the United States, governmental control over private land is held by the individual states. The police powers to regulate land use (including planning and zoning) are usually delegated by the states to local governments. As Patterson (1979) states:

Local governments are entirely dependent on the state governments for the powers which enable them to plan and implement plans and policies. These powers are conferred by means of state planning enabling acts and supplementary legislation. Planning enabling legislation dates back to the 1920s in most states and much of it is modeled on the Standard State Zoning Enabling Act of 1922, and to a lesser degree on the Standard City Planning Enabling Act prepared by the U.S. Department of Commerce in 1926.

In most cases, planning and land use regulation are options rather than requirements for local governments.

Attempts by a noisemaker and/or regulatory agency to influence local land use management should be cognizant of two factors (Engleman and Raspet, 1983). The first is the level of sophistication of the local government structure. The second is the presence or absence of enabling legislation by the state in which the noise/land use issue takes place. According to Engleman and Raspet (1983), a minimum of six different topics of legislation should be examined: (1) planning enabling legislation, (2) regional organization and intergovernmental coordination, (3) zoning and setback legislation, (4) annexation, (5) plats and subdivision legislation, and (6) economic and community development. Both state legislation and the sophistication of the local government structure can be key determinants in the selection of appropriate land use management techniques.

## DEFINING NOISE COMPATIBLE LAND USE

Noise compatible land use management can be justified in principle as a means of minimizing the unwanted spillover effects that might otherwise result from unmanaged or unregulated land use. Effective implementation of any technique first requires that some basic compatibility guidelines be established, such as those shown in Figure VI-1.

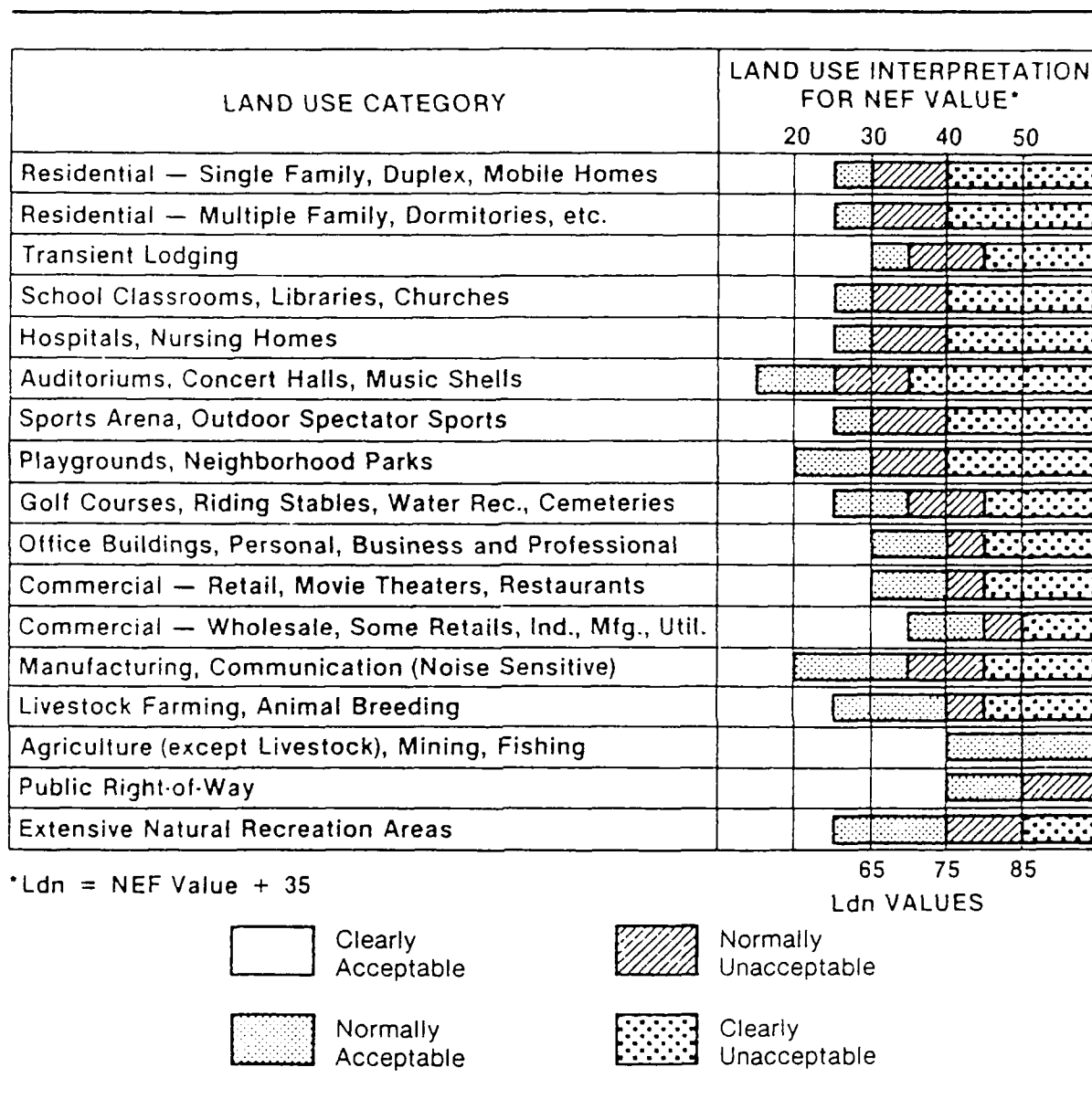
While Figure VI-1 presents some basic guidelines, more detailed land use planning standards should be used and are available in the Standard Land Use Coding Manual (SLUCM). The SLUCM guidelines were published in 1965 by the Federal Highway Administration (FHWA) and what is today the Department of Housing and Urban Development (HUD). These exterior noise standards continue to be recommended for use by local governments and can be found in a variety of sources (Magan, 1979). The FAA (1983) has recently published an expanded version.

## IDENTIFICATION AND EVALUATION OF AVAILABLE TECHNIQUES

This section identifies and evaluates specific techniques available to a municipality for noise compatible land use management. A framework is presented for categorizing the large range of techniques available. The evaluation of individual techniques is presented in an extended outline format, using descriptive notes rather than a full text discussion. The outline is not intended to be either an exhaustive or a definitive review of available techniques. The subject can only be fully addressed in a larger format. However, it does serve to illustrate the range of techniques available and provides general insights on the effectiveness and possible application of individual techniques.

Figure VI-2 shows the major categories of land use management techniques potentially available to a municipality. The seven major categories can be broken into either direct or indirect government actions. In the outline that follows Figure VI-2, individual techniques are classified and discussed within the seven major categories. An introductory statement is given for each category. Brief notes are given for each technique under the headings of Description, Physical Result, Situation Where Most Applicable, Effectiveness, Cost to the Municipality, Enforcement Mechanism, and Comments. Not all the headings are covered for each technique, the information being either unavailable or self-explanatory.

The outline is a compilation of information from six primary sources (Bragdon, 1984; Cline, 1986; Engleman and Raspet, 1983; FAA, 1983; Federal Interagency Committee on Urban Noise, 1980; and FHWA, 1974). Many of the notes in the outline are taken either directly or partially from a variety of tables or text contained in these sources. The reader interested in further information on the topic will find it useful to begin his or her search with these sources.



Source: HUD, 1985.

Figure VI-1. Land Use Compatibility Guidelines

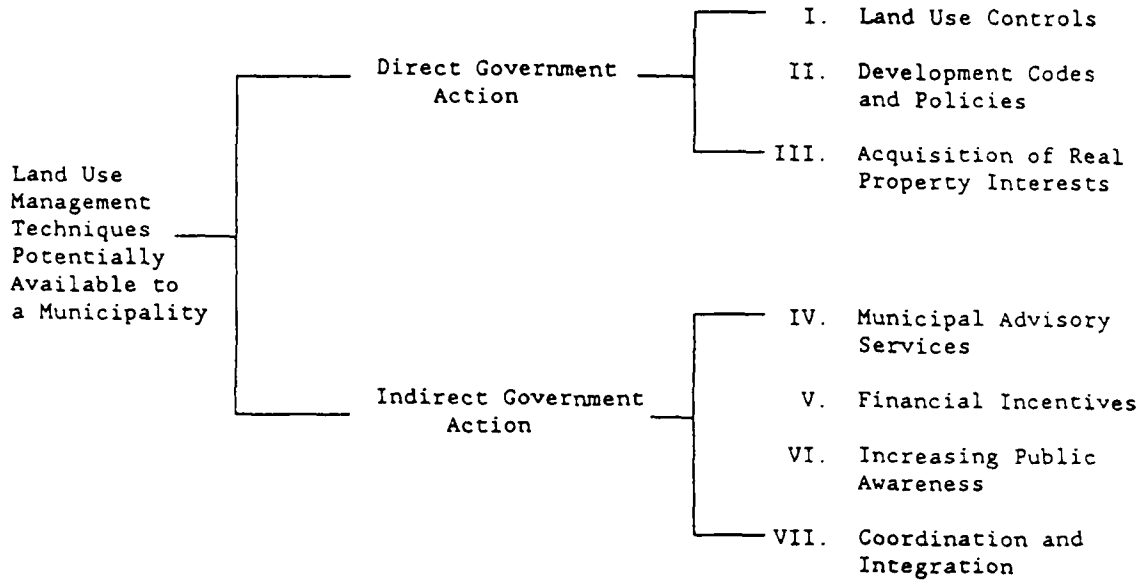


Figure VI-2. Land Use Management Techniques

## Outline of Available Techniques

### I. Land Use Controls

**Introduction:** Direct municipal regulatory control can be used to implement noise compatible land use. While a municipal noise ordinance is an available administrative technique that can affect noise reduction at the source, it may have little effect on land use. Thus, this section focuses on the various types of zoning as land use control mechanisms.

#### A. Zoning

**Description:** Zoning can be defined as an exercise of the police power of the state, as delegated to local governments. It allows communities to enact ordinances or bylaws protecting the public health, safety, morals, and general welfare of their citizens. The operative procedure is to specify what type of land use is permitted within each zoning district of the local jurisdiction.

##### 1. Zoning for Compatible Land Uses.

**Physical Result:** Prevention of incompatible land use.

**Situation Where Most Applicable:** Where demand for typically compatible land uses is significant.

Effectiveness: High.

Cost to the Municipality: Insignificant if zoning exists.

Enforcement Mechanism: Denial of building or special permits.

Comments: Should be based on a comprehensive plan. May require enabling legislation to use noise as a criterion. Not retroactive and can be removed on short notice. Will only work if a community has a noncumulative zoning law. (In cumulative zoning, all "higher" ranked land uses such as residential, are permitted in lower use zones.) Possibility of "overzoning" always exists, may leave land underutilized. Zoning may have either positive or negative effects on local tax base, depending on kind and degree of development that results. Usually not retroactive and will not impact current tax base.

## 2. Zoning to Require Buffer Areas.

Physical Result: Buffer strips.

Situation Where Most Applicable: Where noise is at ground level. Where land values and/or lot sizes permit.

Effectiveness: High.

Cost to the Municipality: Insignificant if zoning exists.

Enforcement Mechanism: Denial of building or special permits.

Comments: Easy to implement in low-density areas. Not effective for airborne aircraft. May require enabling legislation.

## 3. Zoning to Require Berms or Barriers.

Physical Result: Path disruption.

Situation Where Most Applicable: Where noise source is at ground level and other physical techniques are not practical.

Effectiveness: Varies with the terrain and the type of noise involved.

Cost to the Municipality: Insignificant if zoning exists.

Enforcement Mechanism: (1) Denial of building or special permits, (2) occupancy permits, (3) performance bonds.

Comments: Often not aesthetically desirable. May require enabling legislation.

## 4. Zoning to Limit Building Height.

Physical Result: Path disruption.

Situation Where Most Applicable: When terrain makes this technique effective.

Enforcement Mechanism: Denial of building or special permits.

Comments: Effective in limited situations.

#### 5. Zoning to Require Acoustical Building Techniques.

Physical Result: Insulation, isolation, and adsorption.

Situation Where Most Applicable: Where other measures are inadequate.

Effectiveness: High for interiors, low for exteriors.

Enforcement Mechanism: (1) Denial of building or special permits, (2) occupancy permits, (3) performance bond.

Comments: Can cause unnecessary building costs.

#### 6. Zoning to Allow Cluster or Planned Unit Development.

Physical Result: Buffer strips, site design, path disruption.

Situation Where Most Applicable: Where large undeveloped areas exist.

Effectiveness: High.

Cost to the Municipality: Additional review procedure.

Enforcement Mechanism: Approval procedure.

Comments: Significant potential benefits but can be misused. Builders can incorporate buffer areas without reducing the number of units. May require enabling legislation.

## II. Development Codes and Policies

Introduction: Zoning is never the only legal tool available to a municipality or local government to control incompatible land use. The following seven items may all be used to prevent incompatible land uses from coming into existence.

### A. Building Codes

Description: A building code prescribes the basic requirements that regulate the construction of structures. These requirements may include specification for acoustical construction practices that come in four basic forms: (1) specific construction techniques, (2) specific attenuation characteristics such as mandatory sound transmission class (STC) levels, (3) allowable noise levels after construction such as peak levels in bedrooms at night, and (4) interpretive regulations with precise standards left up to the discretion of the building inspector.

Physical Result: Insulation, isolation, adsorption.

Situation Where Most Applicable: Where individual lots are being developed. Where interior noise exposure can be reduced to acceptable levels and buildings should otherwise be prohibited.

Effectiveness: High for interiors, low for exteriors.

Cost to the Municipality: Insignificant if building code enforcement already exists.

Enforcement Mechanism: (1) Denial of building or special permits and (2) occupancy permits.

Comments: Limited to few physical techniques. Noise level reduction (NLR) up to 35 dB (15 dB above normal construction). Outdoor environment not protected. May require enabling legislation to use noise zones for building code restrictions. Difficult to apply retroactively. Local opposition to increased building costs possible. Related to energy conservation. Does not address annoyance to low-frequency vibrational energy associated with impulse noise.

## B. Subdivision Regulations and/or Site Plan Approval

Description: The means by which a local government can ensure that noise reduction considerations are included in the lot layout, design, and improvements made in new residential developments.

Physical Result: Buffers, berms, barriers, site orientation, path disruption.

Situation Where Most Applicable: Where large developments rather than individual buildings are anticipated. Where portions of development projects fall within noise exposure areas.

Effectiveness: High in certain applications.

Cost to Municipality: Insignificant if subdivision control mechanism already exists.

Enforcement Mechanism: (1) Denial of building or special permits and (2) occupancy permits.

Comments: May require enabling legislation. May not apply to airborne aircraft. Buffer typically required of developers may not be adequate protection from the noise emitted from U.S. Army training ranges.

## C. Health Codes

Description: The health code in a community establishes requirements protecting individuals from adverse or endangering elements (i.e. poor sanitation facilities). Communities unable or unwilling to

use zoning ordinances can utilize the health code to protect people from noise impacts.

Situation Where Most Applicable: Anywhere state law permits.

Cost to the Municipality: Insignificant addition to present Health Department costs.

Enforcement Mechanism: Varies, possibly permit system.

Comments: Can be highly effective, but if low-frequency vibration exists, then any permitted design would have to be able to attenuate vibration as well as noise. Building designs which reduce vibration are in the developmental stage.

#### D. Special Permits

Description: Special exceptions or conditional use permits build flexibility into a zoning ordinance by allowing for land uses which are generally prohibited in high-noise areas. Permit is granted on the basis of achieving some performance standard.

Situation Where Most Applicable: Anywhere a permit-granting system exists or can be started.

Cost to the Municipality: Limited cost if special permit mechanism already exists.

Enforcement Mechanism: Denial of permit.

Comments: Site-specific analysis required for each case. May require enabling legislation.

#### E. Special Districts

Description: Noise-impacted areas may cross the boundaries of several districts. Special overlay zones based on noise contours could be created and superimposed over regular districts. An organized governmental entity may be established and empowered with certain functions (i.e. enforcing special regulations).

Comments: Not commonly used, but this technique may reduce legal and administrative problems for noise compatible land use management.

#### F. Special Use Designations

Situation Where Most Applicable: Anywhere unique or special land characteristics exist (cultural or historic, scenic, wetlands, floodplains, prime agricultural lands, water supply sources).



Comments: Such areas may be noise exposed, and those designations will normally assure noise compatibility. May require special legislation.

#### G. Capital Improvements Program

Description: A capital improvements program is the multi-year scheduling of planned public physical improvements, such as new streets, water and sewer lines. Coordinating the program with a comprehensive plan will provide improvements to designated growth areas and not to areas affected by noise, thus promoting noise compatible residential development.

Situation Where Most Applicable: Anywhere, but limited by the need for public physical improvements.

Comments: Government-constructed utilities, streets, and facilities should be sited to encourage compatible use and be in themselves compatible.

### III. Acquisition of Real Property Interests (Municipal Ownership)

Introduction: The acquisition of noise-impacted or potentially impacted property is the best way to ensure noise compatible land use. Title to real property contains a set of property rights often referred to as a "bundle of entitlements." Full or partial acquisition of property rights is one direct land use control available to a local governmental unit. Once property is acquired, the options are (1) leave the land undeveloped, (2) develop it with compatible uses, (3) sell it with appropriate covenants on the deed to ensure noise compatible development, or (4) lease the land with appropriate restrictions.

#### A. Fee Simple Purchase

Description: Property rights to a parcel of land are purchased in full.

Physical Result: Buffer strips, prevention of incompatible use.

Situation Where Most Applicable: Where development pressures make less absolute measures inadequate. Where noise levels are extreme.

Effectiveness: High.

Cost to the Municipality: High.

Enforcement Mechanism: Possession.

Comments: Attempts to contain worst noise effects within right of way or site. May require enabling legislation. Can be an undesirable policy for municipality.

## B. Fee Purchase and Resale with Development Restrictions

Situation Where Most Applicable: Where other measures are impractical.

Comments: Public authority may be reluctant. Local government may object to controls. Business may object to government becoming developer. Dependent on demand feasibility for compatible use. May require enabling legislation.

## C. Easements Purchase

Description: An easement is the right of the owner of one parcel of land to use the land of another (such as for aircraft low-altitude flyovers) or to restrict the uses to which that other owner may put his land (such as purchase of development rights).

Physical Result: Buffer strips, prevention of incompatible land use.

Situation Where Most Applicable: Where other measures are impractical. Where possible at low cost.

Effectiveness: High.

Cost to the Municipality: Often insignificant.

Enforcement Mechanism: Possession.

Comments: May be more practical than fee simple purchase. May require enabling legislation.

## D. Conservation Trust

Description: A variation of an easement. The owner of a parcel of land gives the land to the community to be held in a conservation trust for a specified length of time. The owner retains a residual right to the land as a long-term investment.

Physical Result: Buffer strips.

Situation Where Most Applicable: Where the trust benefits the municipality in general and does not merely benefit an individual landowner at the expense of taxpayers.

Comments: Can be an inexpensive way of controlling land to regulate orderly community growth as well as potential noise incompatibility.

## E. Agricultural Land Preservation District

Situation Where Most Applicable: Where land is suitable.

Comments: Requires appropriate legislation. Minimum site size of

50 acres is typical and usually allows a single farm residence. Presents possible bird strike hazards near airports.

#### F. Land Banking

**Description:** A system of land acquisition by a governmental unit for the purpose of implementing a public land use policy. Land is placed in a temporary holding status to be turned over for future development.

**Physical Result:** Prevention of incompatible land use.

**Situation Where Most Applicable:** Where large undeveloped areas remain, and potential development pressure exists.

**Costs to the Municipality:** The cost of the original purchase can be recovered and transferred into the cost of future public or private use.

**Comments:** Requires state enabling legislation. Allows for the promotion of orderly and noise compatible development. A piece of land can remain undeveloped until there is a use identified which is compatible with land use policy.

#### G. Tax Increment Financing

**Description:** A method used to promote compatible land development. After designating tracts of land for development, the municipality solicits developers for the area. The municipality can also buy the tract and make improvements. Funding is obtained by selling revenue bonds. The initial assessment base of the land for other taxing bodies is frozen until the retirement of the bonds. As improvements are made, property value of the land will increase. The land is taxed at the same annual tax rate of all the taxing bodies, thus producing the increment funds with which to retire the bonds.

#### H. Zoning by Special Assessment Financed Eminent Domain (ZSAFED)

**Description:** Under this zoning approach, the landowner in high-noise areas is compensated for his or her diminished right to develop land (taken under eminent domain). The compensation awards are financed by capturing windfall land value increases caused by zoning permission to develop for intensive use in other areas. Property owners adversely affected by noise are compensated through a fund financed by taxing property owners beneficially affected by zoning-related property value changes.

**Cost to the Municipality:** Administrative costs are likely to be high.

Comments: Currently not in use, only proposed for noise compatible land use management

#### IV. Municipal Advisory Services

Introduction: A municipality can provide a variety of services which, when used as a supplement to other administrative measures, can promote noise compatible land use.

##### A. Architectural Review Boards

Description: A local board, either official or unofficial, that provides a municipality with advice on noise compatible design control.

Situation Where Most Applicable: Where there is appropriate staff or funding.

Effectiveness: Low, dependent on enforcement mechanism.

Cost to the Municipality: Often insignificant, depends on administration.

Enforcement Mechanism: Varies

Comments: Site-specific analysis for each case.

##### B. Municipal Design Assistance

Description: A municipality may have the technical ability on its staff to provide an informal design review service.

Situation Where Most Applicable: Anywhere there is appropriate staff or funding.

Effectiveness: Low.

Cost to the Municipality: Insignificant.

Enforcement Mechanism: Information, public pressure.

Comments: Can be very expensive. Allows inclusion of noise mitigation measures such as building attenuation, siting modification, berms, barriers, etc., in design plans.

##### C. Information Libraries

Description: Maintaining a convenient library of acoustical design and construction techniques along with some background literature on expected noise levels can be an effective information source. It can provide local designers, builders, and developers with otherwise unavailable information which they may be quite willing to use.

Situation Where Most Applicable: Anywhere, but especially where

municipal staffing or funding is otherwise low.  
Comments: Provides a passive advisory service.

## V. Financial Incentives

Introduction: While financial incentives may not have the absolute strength of enforcement that municipal ownership or legal regulations have, they can be effective stimuli to noise compatible land use management.

### A. Municipal Tax Incentives

#### 1. Property Tax Incentives.

Description: Preferential tax assessment of land allows the owner to pay reduced taxes and thereby reduces the incentive to sell or develop land because of high property taxes.

Physical Result: Prevention of incompatible land use.

Situation Where Most Applicable: Where tax pressures exist on owners of undeveloped land.

Effectiveness: Varies with response.

Enforcement Mechanism: Incentive.

Comments: Requires enabling legislation. Easy in many cases to implement. Cannot prevent incompatible development but can allow economically productive compatible land use.

#### 2. Flat Rate Lot Tax

Description: Lots in a noise-impacted area can be assessed at a flat rate regardless of size, rather than on a "per square foot" basis.

Physical Result: Development of on-lot buffer strips.

Effectiveness: Limited application.

Comments: Provides incentives to develop larger lots which make on-lot buffer strips possible.

#### 3. Advantageous Assessment of Acoustic Construction.

Description: The extra cost (and value) of acoustic construction such as insulation, air conditioning, or double-glazed windows can be assessed at little or no value.

### B. Relaxation of Municipal Regulations

Description: The relaxed enforcement of certain provisions to local regulations can be used to encourage builders and developers to

utilize noise compatible construction.

Physical Result: Varies.

Comment: Problems will result if policy is applied illegally or arbitrarily. Can set dangerous precedents. The person who benefits must be able to provide the desired acoustical benefit.

## VI. Increasing Public Awareness

Introduction: Awareness or cognition of the severity of noise impacts may affect the rationality of individual land use choices. In increasing this awareness, a municipality can either provide information to the public describing the noise environment or require that it be provided.

### A. Citizen Education

Situation Where Most Applicable: Anywhere.

Comments: Can be an important factor in determining the marketability of homes and other land uses. Can have a direct effect on developers and builders. Use in combination with other actions.

### B. Prior Notice of Noise Levels to Renters and Purchasers

Situation Where Most Applicable: Anywhere.

Comments: Noise levels in a community can be measured and recorded. Public disclosure of these levels can be required by local ordinance. Enables renters and purchasers to choose environment with full information. May reduce or eliminate subsequent complaints or damage claims.

## VII. Coordination and Integration

Introduction: A number of opportunities exist for coordinating and integrating noise impact considerations with the operating procedures of other government actions, within both the local authority and the larger federalism.

### A. Incorporating Noise Issues into Comprehensive Planning Process

Description: The comprehensive plan is an official document projecting future use and development of land.

Situation Where Most Applicable: Where comprehensive planning process is established, particularly where controls (zoning) must implement plan.

Comments: Works best when noise is considered a basic suitability factor along with others such as slope, soil conditions, etc. Should be addressed in all types of plans. May require enabling legislation

#### B. Incorporating Noise Issues into Environmental Management Programs

Situation Where Most Applicable: Where programs such as: areawide waste management, air quality, coastal zone management, prime and unique agricultural lands, and floodplains and wetlands are established.

Comments: These programs influence land use policy.

#### C. Environmental Review

Description: Deals with the assessment of potential environmental impacts (including noise and land use consequences) resulting from public projects.

Situation Where Most Applicable: Anywhere environmental assessments or environmental impact statements are required.

Comments: An indirect control, but comprehensive review can increase awareness of noise. May discourage inappropriate projects. Mechanism to propose mitigation measures.

#### D. Intergovernmental Coordination

Description: A number of possibilities for intergovernmental coordination exist, such as Office of Management and Budget Circular No. A-95. This is a regulation requiring coordination of federal and federally assisted programs and projects with each other and with state, areawide, and local plans and programs, utilizing a series of state and regional clearinghouses.

Situation Where Most Applicable: Anywhere federal and federally assisted projects are proposed.

Comments: Allows identification of noise problems in the review and comment of federal and federally assisted plans, programs, projects. Indirect control.

### FREQUENCY OF USE

Two recent studies of land use management in areas adjacent to airports provide some quantitative estimates on the relative frequency of use for various techniques.

The studies are similar in character and scope. In each case, techniques are identified and both absolute and relative usage are presented. The results of the studies are shown in Tables VI-1 and VI-2. While many of the techniques have already been identified and described in this chapter, the authors specific definitions have been included.

Bragdon (1984) has surveyed the land use controls employed as noise mitigation strategies at nearly 200 U.S. airports. Table VI-1 summarizes the results of that survey. Thirteen primary land use control techniques are identified and ranked according to frequency of use among airport communities. Zoning and comprehensive planning stand out as the two principal techniques employed, each used in over 50 percent of the communities. The two categories covering acquisition of property rights (fee simple purchase and aviatational easements) were also prominent techniques.

A report by the FAA (Cline, 1986) contains a compilation and summarization of noise control strategies used at 439 airports in the U.S. A total of 37 categories for noise abatement and mitigation are identified and described. Twelve of those categories are related to land use management in the areas adjacent to the airports. Table VI-2 is constructed from that report and includes a brief description of the 12 land use management categories which are ranked according to the frequency of use. Similar to the Bragdon (1984) study, the FAA report also shows zoning to be the primary land use technique. Acquisition of either full or partial property rights (purchase of land or noise easements) was also commonly used.

## **DEVELOPING COORDINATED MANAGEMENT STRATEGIES**

As shown in this chapter, there is a great range of administrative techniques available for implementing noise compatible land use management. While some techniques may be considered individually, it is most likely that a combination of techniques will be the most effective management strategy. The FHWA (1974) has identified eight variables that should be considered at the local level when selecting the most appropriate management strategy or combination of techniques:

- (1) Timing of implementation
- (2) Degree of existing development
- (3) Physical techniques desired
- (4) Degree of control desired
- (5) Financial considerations
- (6) Administrative structure of local government
- (7) The local political situation
- (8) Applicability under state law



TABLE VI-1  
SURVEY OF LAND USE CONTROLS NEAR 198 U.S. AIRPORTS

Rank Order	Land Use Controls	Number	% of Total (198)
1.	<u>Zoning</u> : Zoning is a form of police power that enables government to enact ordinances protecting the public health and safety, and welfare of its citizens	116	58.6
2.	<u>Comprehensive Plan</u> : An official public document adopted by a government and protecting the future uses of land development.	108	54.5
3.	<u>Land Acquisition</u> : A fee simple purchase of land around an airport is the best way to prevent incompatible land uses. This action may be taken by either the installation/airport or a local government body.	40	20.2
4.	<u>Aviation Easement</u> : An easement is the right of the owner of one parcel of land to use the land of another (such as for low-altitude flyovers) or to restrict the uses to which that other owner may put his land to.	37	18.7
5.	<u>Real Estate Sales Disclosure</u> : Disclosing noise levels to property buyers in written real estate agreements may help to reduce noise/land use conflicts.	34	17.2
6.	<u>Building Code</u> : A building code prescribes the basic requirements that regulate construction of structures.	32	16.2
7.	<u>Capital Improvements</u> : Capital Improvements programming is the multi-year scheduling of public physical improvements.	18	9.1
8.	<u>Development Rights</u> : A title to real property contains several rights. Purchasing development rights may help to prevent incompatible land uses.	10	5.1
9.	<u>Site Designs</u> : Site design deals with the process by which a review procedure is established through a public agency whereby environmental factors are considered into a plot or land plan.	9	4.5
10.	<u>Land Banking</u> : The term "land banking" can be defined as a system in which a government acquires a substantial fraction of land in a region that is available for future development for the purpose of implementing a public land use policy.	7	3.5
11.	<u>Tax Incentives</u> : Special or preferential tax assessment of land by a local government allows an owner of a piece of property to pay lower or no property tax.	5	2.5
12.	<u>Environmental Impact Review</u> : Environmental review deals with the assessment of public-related projects that may have some potential impact on land use and the public interest.	4	2.0
13.	<u>Subdivision Regulations</u> : Subdivision regulations are the means by which a local government can ensure that proper lot layout, design, and improvements are made in new residential developments.	4	2.0

Source: Adapted from Bragdon, 1984.

TABLE VI-2  
SURVEY OF LAND USE CONTROLS NEAR 439 U.S. AIRPORTS

Rank Order	Land Use Controls	Number	% of Total (439)
1.	<u>Zoning</u> : Any use of local zoning laws to restrict incompatible land.	133	30
2.	<u>Purchase Land for Noise Control</u> : Airport acquired incompatible land.	77	17.5
3.	<u>ANCLUC Plan</u> : An Airport Noise Control and Land Use Compatibility Plan has been approved.	68	15.5
4.	<u>Local Noise Law or Ordinance</u> : A local noise law or ordinance which is aircraft/airport related.	49	11
5.	<u>Noise Easements</u> : Purchase of limited property right in noise impacted areas.	49	11
6.	<u>Development of an EIS</u> : One or more Environmental Impact Statements have been completed.	33	7.5
7.	<u>Part 150 Noise Exposure Map Approved</u> : A noise exposure map has been approved by the FAA in accordance with FAR Part 150.	24	5.5
8.	<u>Part 150 Noise Compatibility Plan Approved</u> : A plan has been approved by the FAA in accordance with FAR Part 150.	15	3.4
9.	<u>Building Codes and Permits</u> : Local government-imposed requirements in noise impacted areas.	14	3.2
10.	<u>State Noise Law</u> : A state law related to aircraft, airport noise control.	12	2.7
11.	<u>Capital Improvements</u> : Actions taken by local government or airport sponsor to restrict development in noise impact areas and to direct noise sensitive development to more compatible areas.	9	2.0
12.	<u>Purchase Assurance</u> : A purchase guarantee applied to noise sensitive properties within lightly or short-term noise areas which assures salability and helps to maintain viable neighborhoods.	4	0.9

Source: Adapted from Cline, 1986.

Administrative techniques for land use management vary in their level of stringency and general effectiveness. Many are valuable only when used in conjunction with one or more other administrative techniques. Furthermore, administrative solutions such as local land use management will most likely work best (in terms of effectiveness, cost, and desirability of results) when coordinated with the actions of the other parties (noisemakers, federal, or state regulatory bodies) involved in a noise/land use issue.

## VII. DISCUSSION AND CONCLUSIONS

Traffic noise is commonly cited as the most pervasive noise problem in the urban environment. Aircraft noise around airports is a less pervasive but more intense and localized form of noise. Military installations can be compared to airports as a noise source that can potentially impose severe impacts on entire communities. As a general statement, noisier weapons and aircraft, more mobile noise sources capable of impacting a wider area, and encroaching urban growth all point toward the potential for increasing noise conflicts around military installations.

The initial problem in approaching a noise/land use issue is the selection of the proper perspective. One approach is to view noise as an environmental pollutant and frame the issue in terms of transgressors and victims. The issue may also be seen as one of conflict between competing interests, each asserting a legally or socially validated position. This idea of conflicting interests can be expanded on to recognize the often symbiotic relationship between noisemaker and noise receiver. Strategies based on the concept of preventing conflict may be particularly attractive from the perspective of the military. The need to preserve mission capability and the limited unilateral power to ensure local noise compatible land use may often require that some program of interaction with the community be implemented.

Noise is a subjective environmental phenomenon. The management application of a noise metric is an attempt to describe the full noise environment, which includes both sound exposure level and individual or group responses. The selection of a noise metric and prediction or monitoring program can influence management strategies. Impulse noise requires special consideration such as the use of a C-weighted descriptor.

While the relationship between community annoyance and sound exposure level is strong, the relationship between complaints and either annoyance or exposure is unclear. It does seem clear that noise abatement policies must be geared to annoyance rather than complaint behavior. Yet, handling public complaints is a sensitive management area. Unsatisfied complainants may be moved to further directed behavior (litigation or political pressure). Standardizing complaint-handling procedures is a valuable organizational measure that can influence public attitudes and improve future problem-solving capabilities.

Within the last 30 years, civil litigation over excessive noise has increased dramatically. Preemptive federal legislation, passed in the 1970s has stirred the debate over federal versus local control of noise sources. While a number of important U.S. Supreme Court cases have transpired and are reviewed, many legal issues remain unclear. One implication is that noise-producing activities which are responsible for meeting federal requirements cannot be regulated by any lower police-power agency.

In meeting federal requirements, a noisemaker strengthens its position against potential litigation.

A fundamental management approach for major noise management programs in the U.S. has been the use of noise levels or quantitative standards. Programs can be distinguished by the type and intent of the noise levels specified. Commonly, noise levels used for planning and land use guidelines are based on the expected percentage of the population "highly annoyed." The effect on land use management of linking policies to noise levels is that land can be classified into noise zones. The levels which define the zones are constant but the shape of the zones on the noise map will change as the noise environment changes. A viable management approach may involve focusing on projected changes in zones rather than the exact physical location of a noise contour. The ability to identify current and predicted noise zones arms the program manager with a powerful tool for land use planning.

The available tools for implementing management objectives can be categorized into four broad groups: physical techniques, organizational measures, public relations/interaction measures, and administrative techniques. A wide variety of individual techniques are identified and evaluated. The ability to attenuate noise impacts through technological or operational means was shown to be source-specific. Some sources such as vehicular noise are more amenable to physical solutions than are other sources such as impulse noise from detonations or explosions. Administrative measures such as noise source emission regulations have been widely used, and with mixed results. Financial incentives have rarely been applied in noise management. While broad categorical conclusions about management approaches should be avoided, the past reliance on physical solutions appears untenable considering the full range of techniques available.

While noise pollution may not be the banner issue it was in the 1970s, noise/land use issues have not gone away. Noise management remains one of the most difficult environmental problems. Seneca and Tausig (1984) offer the following summarization:

Laws, regulations, and zoning techniques have been the major instruments of noise control, and these policies have been largely ineffective. The basic causes of this failure are the diffuse and broad-based nature of the noise sources, the growth in these sources, the difficulty of enforcing legal remedies, and the conflict of noise control with economic activity and modern urban life. In many cases, noise is a relative problem and although my neighbor and I may both fight for a local prohibition of trucks from our residential streets, we may disagree considerably in the proper volume of my stereo, the all-night running of his air conditioner, the use of my child's minibike, or the barking of his dog.

Quite often the issue reduces down to conflict between neighbors, each asserting the strength of his or her own claim. Expanded government controls, increased use of economic incentives, and the development of new technology are all seen as potential remedies to noise/land use problems. Nevertheless, the conclusion which cannot be avoided is that there are no simple solutions. The reader looking for quick "fixes," either physical, regulatory, or economic, will be disappointed. What surfaces instead is the need for "process-oriented" approaches, which recognize that identifying noise impacts and working with all affected parties to evaluate alternative solutions must be an ongoing activity.

Fortunately, the search for answers to these questions of conflict does not come up empty. Within the last decade, a number of similar noise management programs have emerged. They are characterized by an attempt on the part of a noisemaker and/or regulatory body to identify noise zones and involve all affected parties in a cooperative effort aimed at reducing noise impacts. The AICUZ, ICUZ, FAR Part 150 programs seem to offer the most realistic possibility for solving current or potential noise problems. The effectiveness of many techniques is greatly increased when they are introduced as preventive measures (i.e. zoning), and one emphasis of these programs is on the prevention of future conflicts. There are examples of both success and failure in the implementation of these programs. The probability of success is increased when rigorous noise control efforts are coupled with an ongoing process of interaction with local communities.

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**APPENDIX A:**  
**LIST OF INTERVIEWS AND INTERVIEW QUESTIONS**

## **LIST OF INTERVIEWS**

Steve Alverson, Airport Noise Officer, Stapleton International Airport, Denver, CO.

Bob Armstrong, Federal Highway Administration, Washington, DC.

Bob Bullock, Noise Program Coordinator, Seattle Tacoma International Airport, Seattle, WA.

Jeffrey Bunting, Dallas-Fort Worth International Airport, Dallas-Fort Worth, TX.

Bob Cole, U.S. Army. Fly Neighborly Program. Washington, DC.

Bill Cox, AICUZ Program Manager, Bolling Air Force Base, Washington, DC.

Thomas Duffy, Executive Director of NOISE, Washington, DC.

Herbert Dean, Bolling Air Force Base, Washington, DC.

Dr. Mark Dunning, U.S. Army Corps of Engineers, Institute for Water Resources, Fort Belvoir, VA.

Patrick Graham, Savannah Airport Commission, Savannah, GA.

Judith Hamill, Noise Program Manager, O'Hare Airport, Chicago, IL.

Tim Knapp, Base Planner and ICUZ Program Director, Bergstrom Air Force Base, TX.

Dr. George Luz, U.S. Army Environmental Hygiene Agency, Aberdeen Proving Ground, MD.

James Miller, Department of Housing and Urban Development, Washington, DC.

Fred Minz, Office of Federal Activities, Environmental Protection Agency, Washington, DC.

Geno Patriaca, Community Planner, Davis-Monthan Air Force Base, Tucson, AZ.

Karen Robertson, John Wayne Airport, Newport Beach, CA.

Dr. Paul Schomer, Construction Engineering Research Laboratory, Champaign, IL.

Dr. John Singley, U.S. Army Corps of Engineers, Institute for Water Resources,  
Fort Belvoir, VA.

Steve Starley, Program Director for the Federal Aviation Administration,  
Washington, DC.

Lt. Col. J. Stratta, U.S. Army Environmental Division, Washington, DC.

Steve Veechi, Metropolitan Airport Commission, Minneapolis, MN.

David Wert, Department of Comprehensive Planning, Clark County,  
Las Vegas, NV.

Doug Widener, Veterans Administration, Washington, DC.

Alan Zusman, Naval Facilities Engineering Command, Alexandria, Virginia.

### LIST OF INTERVIEW QUESTIONS

- I. Describe the noise environment that you manage or are concerned with (the types of noise involved, the noise source(s), and noise impact receivers).
- II. What are the current and future issues in noise management?
- III. Describe the noise management program that is currently in place. Are there any procedural or policy changes under consideration?
- IV. What are some commonly applied management tools for dealing with noise issues, and how broad of an applicability do they have?
- V. How effective has the management program been in handling noise/ land use issues? ...where effectiveness might be defined using such criteria as (1) preservation of mission/agency directives, (2) minimization of public exposure to noise, (3) maintenance or improvement of relations (between the noise source and the noise receivers, and (4) maintenance or improvement of problem-solving capability.  
  
Are there any quantified results available?
- VI. What are the implementation requirements for your management program in terms of resources, cooperation, etc.

- VII. What lessons can be learned from your management approach to noise?
- VIII. Is it possible to acquire any reference documents or additional sources of information from you?
- IX. Can you suggest any key references or individuals to be contacted?

Name, address



## APPENDIX B:

### ANNOTATED BIBLIOGRAPHY

The intent of this annotated bibliography is to present a representative sampling of the available literature on noise, with particular emphasis on material from the last decade. As a group, the selections also focus on management aspects of the noise field. The objective of the collective annotations is to both survey major management issues and to aid the reader in pursuing further research interests.

Several additional publications deserve special note as sources of information in the noise field. Perhaps the most comprehensive is Bragdon's 1979, Noise Pollution: A Guide to Information Sources, which presents numerous brief annotations on noise literature, categorized according to subject areas. A listing of all periodicals and indexes concerned with noise is included. Annotated bibliographies of much smaller size and scope are also available (i.e. FHWA, 1980h; Federal Interagency Committee on Urban Noise, 1980). The proceedings of the annual "Inter-Noise" and "Noise-Con" conferences contain numerous short papers on a variety of noise subjects, albeit with primary emphasis on acoustical engineering. Finally, there are a number of valuable textbooks available, ranging from comprehensive reviews (Tempest, 1986) to works on specific topical areas such as industrial noise control (Cheremisinoff and Ellerbusch, 1982), and transportation noise (Nelson, 1987).

Bell, Robert. B., and Lisa M. Bell. 1980. Airport Noise: Legal Developments and Economic Alternatives. Ecology Law Quarterly 8(4):607-53.

The authors examine current federal and local efforts to control airport noise problems, review applicable federal legislation and case law, and suggest an alternative approach to airport noise, based on a system of economic incentives.

An introductory discussion of the health effects of airport noise sets the stage for the analysis. Although present research is inconclusive, there is growing indication that airport noise may cause significant physiological and psychological harm in addition to annoyance. It is estimated that over eight million Americans live in areas exposed to disruptive and possibly harmful noise.

A degree of traditional local control over airport noise has been preempted in recent decades by federal legislation and regulatory control. The exact locus of control has often been unclear. As the authors state:

The courts have played a significant role in policy development by establishing liability rules and by identifying the limits of both local power and federal preemption of noise regulation.

Beginning with an amendment to the Federal Aviation Act in 1968, and followed by the Noise Control Act of 1972 (as amended by the Quiet Communities Act of 1978), Congress has passed several pieces of legislation mandating that the FAA should regulate aircraft noise. Critical issues have included the FAA-EPA relationship and federal involvement in local airport planning efforts. Federal regulation of aircraft noise, in the form of FAR Part 36, has focused on emission standards for newly manufactured aircraft and existing aircraft (through retrofitting).

In the 1962 inverse condemnation ruling, the case of *Griggs v. County of Allegheny* established the airport proprietor as singularly liable for the taking of property due to airport noise. Subsequent cases have maintained federal control over aircraft in flight, and established the proprietor's right to control airport uses (on the ground) through non-discriminatory restrictions.

A 1976 FAA retrofit rule, requiring older aircraft to comply with FAR Part 36 emission standards, has been an exorbitantly costly measure. As an alternative, a noise pollution charge system for noisy aircraft is proposed. It would improve the distribution of noise without significant cost by providing an incentive for carriers to reroute noisy aircraft to less noisy airports (the emphasis of the charge system being on total airport

noise rather than single aircraft emission levels). It would also allow carriers to make efficient trade-offs between retrofitting, fleet replacement, rerouting planes, and reducing flights.

The application of economic incentives, as opposed to regulatory control, has been limited in the area of noise management. This article is illustrative of a variety of economic arguments that have been made against the established regulatory scheme for airport noise control.

## 2

Bennett, Steve. 1986. Cost Benefit Analysis and the Feasibility Requirement of the Occupational Noise Regulation. George Washington Law Review 55:123-51.

This article discusses the required inclusion of cost-benefit analysis in the feasibility considerations for engineering controls to meet OSHA workplace standards.

The first occupational noise regulation in the U.S. was promulgated under the Walsh-Healey Act Public Contracts Act of 1969 and was then later incorporated into the standards promulgated under the Occupational Safety and Health Act of 1970. The regulation requires the implementation of feasible engineering controls when noise exposure reaches certain levels. A fundamental issue in subsequent case law has been whether cost-benefit analysis is a requirement of the feasibility determination. The Occupational Safety and Health Review Commission, an adjudicating body that handles appeals to employer citations, has ruled that it is a requirement.

The author argues that, while economic factors should be included within the feasibility determination, a requirement of cost-benefit analysis would jeopardize employee health and undermine the purpose of the regulation. In addition, the current Review Commission interpretation is believed to "strain the plain meaning of the regulatory language." An alternative solution is to require engineering controls in cases where no financial threat to the continued existence of the employer will result.

Any given level of noise source reduction will impose both marginal costs and marginal benefits. Theoretically, some socially optimum level of noise reduction exists. This article illustrates the difficult management choice between imprecise economic analysis and strict regulatory noise standards.

**3**

Bienvenue, Gordon R. 1986. Psychoacoustic Principles Underlying the Interaction of Discrete Tones and Noise in the Phenomenon of Annoyance. In Proceedings, Inter-Noise 86. Pp. 867-72. New York, NY: Noise Control Foundation.

Over 30 years of social survey research have produced some "seemingly contradictory findings in the annoyance literature." The objective of this paper is to review three areas of auditory perception with particular relevance to the understanding of annoyance. The examination of "loudness," masking" and "the critical band" may help to increase the understanding of annoyance.

Loudness is defined as the perception of sound amplitude. Generally a 10 dB increase in sound level is perceived as a doubling of intensity. However, the perception of loudness is frequency-dependent and likely to be greater for broadband sounds in comparison to the narrow bands of sound. In addition, within the noise spectrum the presence of a predominating pure tone is generally believed to increase annoyance.

The "masking" or interference of one sound with the perception of another can impact perceived loudness and annoyance. Perceived loudness in a noise-tone complex is dependent on the degree to which the noise masks the predominating tone. The effectiveness of the noise in masking the tone is related to the concept of the critical band. The general location within the noise spectrum that contains a given pure tone is referred to as the critical band. It acts as an auditory filtering system and any sound energy within the band will "contribute to effectively masking that tone." Thus, it is the tone-to-noise ratio within the critical band that determines perceived loudness. Furthermore, the degree of masking in a noise-tone complex is greater if it primarily contains low-frequency components. This final point is because of wave propagation patterns within the cochlea of the ear and is referred to as the upward spread of masking.

This well-written paper identifies some basic auditory mechanisms that may impact noise-induced annoyance. Understanding these mechanisms will aid in the process of developing and interpreting social survey research.

## 4

Bragdon, C. R. 1984. Airport Noise Monitoring Systems in North America. Sound and Vibration (December):20-21.

This article provides a brief summation of the extent and purposes of permanent noise-monitoring programs.

A noise monitoring system consists of four essential components: (1) remote monitoring stations, (2) central processing station, (3) software, and (4) accessories (map displays and ARTS data). There are three major manufacturers of permanent monitoring systems.

The installation of permanent noise-monitoring systems is an increasingly common management approach to airport noise problems. The first noise management program to include a continuous monitoring system was at John F. Kennedy International Airport in 1967. Today, over 26 systems are in place in the U.S. There are 10 in California alone where the state regulatory scheme favors their implementation. It is asserted that the use of such systems is likely to increase because of the growth of aviation and potential land use incompatibility at communities adjacent to airports.

Monitoring programs are established for a variety of reasons and have both advantages and disadvantages as a management approach. Several of the purposes a monitoring program serves include assessing compliance with regulations, assessing alternative flight procedures for noise control, assisting in investigating complaints, and addressing land use planning issues.

The author provides a concise overview of permanent noise-monitoring programs.

## 5

Bragdon, C. R. 1983. The Control of Airport Noise in the United States. In Proceedings, Inter-Noise 83. Pp. 57-60. Edinburgh, UK: Institute of Acoustics.

This short paper provides a comprehensive overview of commonly applied airport noise control methods based on a cross-section of 141 municipalities and 27 counties in the U.S.

Brief comments are made on each of the 15 identified controls. The controls are grouped into three primary categories:

- (1) Aircraft restrictions: address controls directly applicable to the aircraft
- (2) Aircraft operations: deal with the manner in which aircraft are permitted to operate
- (3) Land use controls: apply to noise abatement methods used in the off-airport communities

This valuable overview provides a useful classification scheme for assessing airport noise control.

## 6

Bragdon, C.R. 1984. Land Planning Noise Control Techniques Around Airports. In Proceedings, Inter-Noise 84. Pp. 635-38. New York, NY: Noise Control Foundation.

This short paper surveys the land planning techniques available for noise control in communities adjacent to airports.

While effective land planning noise controls have not been applied consistently in the U.S., there is increased emphasis on these techniques in recent federal programs. The FAR Part 150 planning program and the Army ICUZ program are examples.

Based on a sample of 198 airports, 13 land use control strategies are ranked according to frequency of use. The most commonly used are zoning and comprehensive planning, occurring in over 50 percent of the cases. In addition, 25 public-related land use techniques are listed and described.

The paper could be useful to planners in identifying the most commonly used land use management techniques for noise compatibility.

## 7

Bruinooge, Jon P. 1979. Development Pressures Near Airports: Fairfax County's Response. Environmental Comment (March):11-14.

This article examines the factors which influenced Fairfax County Virginia's revisions to its noise abatement policy.

Rapid development in areas adjacent to the Dulles International Airport near Washington, DC, had first caused the county to institute noise abatement policies in 1972, which were then drastically modified in 1978. Given that the county has no direct control over operations at Dulles, land use planning and zoning were seen as the only viable policy tools for mitigating the impacts of aircraft noise. However, the planning process was hampered by a series of divergent noise contour forecasts produced by the FAA.

The 1978 policy revisions were a retreat from the earlier outright prohibition of residential development within the NEF 30 to NEF 35 contours. As much as 10,880 acres were released to residential development subject to disclosure statement and sound insulation requirements.

Two major factors can be identified behind the policy change. The first was the lack of a foreseeable market for such a large area zoned for industrial/commercial use. The second involved legal considerations. The development prohibitions were inconsistent with HUD and VA regulations and thus seen as producing an untenable legal position.

This case study provides an example of where reducing the stringency of noise control measures was adopted as a legitimate management strategy.

## 8

Christiansen, Jorgen, Edward J. DiPolvere, and Jon R. Sank. 1986. Community Noise Control Program at Raritan River Steel Company. Sound and Vibration (July):24-29.

This article describes how a regulatory agency, a consulting firm, and a private steel company worked together in developing a noise abatement program.

In 1980, the Raritan River Steel Company (RRSC) began manufacturing steel wire rod from scrap steel at their new minimill at Perth Amboy, New Jersey. Noise complaints from nearby residents began immediately and the Noise Office of the New Jersey Department of Environmental Protection (DEP) quickly became involved.

The RRSC was found to be in violation of state regulations, enacted in 1974, covering stationary industrial sources. The regulations consist of three imaginary sonic walls around a facility whose standards cannot be exceeded. The three imaginary walls are A-weighted sound level, octave band sound pressure levels, and peak sound pressure level for impact or impulsive noise.

The RRSC responded to the noise problem by adopting a voluntary compliance program and hiring Cross Country Consultants. In addition, an administrative order was for-

mulated by the DEP, and agreed to by the RRSC, which outlined a schedule for evaluating alternatives and developing a noise control program. The goal of the program was a 15 dB reduction in A-weighted sound pressure levels with the 240 Hz frequency adopted for acoustical calculations and material specifications.

Noise controls considered include:

- (1) Enclosures for the arc furnace
- (2) Sound absorbing materials inside the shop
- (3) Modular steel acoustical panels
- (4) Exterior sound barrier structures

Finally, however, the RRSC turned to the Wendker Company of Merten, West Germany, and their line of modular thermal/acoustical panels. Engineering support was also contracted with the West German research institute BFI. The actual noise control product selected consisted of exterior panels fastened to a steel frame that was filled with an acoustical blanket of rock wool.

Although testing and monitoring continue, the construction project was complete by mid-1982 and had achieved the desired 15 dB reduction. Total expenditures for this large-scale retrofit program were \$3,600,000 with a construction time of approximately eight months.

The article illustrates the development of an abatement program for a fixed-facility noise source, characterized by cooperation and rapid compliance to state regulations.

## 9

Cline, Patricia. 1986. Airport Noise Control Strategies. Washington, DC: U.S. Department of Transportation/Federal Aviation Administration.

This document provides a comprehensive listing of noise control strategies employed at over 430 U.S. airports. It is based on the Federal Aviation Administration's (FAA) Airport Noise Control Data File, which is updated periodically.

Noise control strategies are divided into 37 categories. The categories range from both in-the-air and on-the-ground procedures for aircraft, to local land use planning measures. Separate listings are given for (1) all strategies used at individual airports, and (2) all airports employing each individual strategy.

This report is an invaluable reference source on the types and relative frequency in use of various airport noise control strategies.



## 10

Cohen, S., and N. Weinstein. 1981. Nonauditory Effects of Noise on Behavior and Health. Journal of Social Issues 37(1):37-70.

This article surveys the research literature on "the non-auditory effects of noise on behavior and health."

Both laboratory and field studies (including social surveys) are reviewed. Emphasis is placed on identifying the relevance of the research for predicting noise effects. The review of noise effects is broken into four major parts: (1) human performance, (2) social behavior, (3) mental health and cognitive development, and (4) general health.

Noise is defined as "sound that is unwanted by the listener because it is unpleasant, bothersome or interferes with important activities or is believed to be physiologically harmful." In the discussion of noise effects on human performance, it is noted that tasks which are generally unaffected by noise tend to be those which are primarily visual or those which involve practiced and repetitive movements. However, novel or unusual noise will interfere with the efficiency of most tasks. In addition to decreased efficiency at the time of the noise, adverse effects such as a lowered tolerance for frustration often occur after noise exposure is terminated. An examination of the literature concerning noise and social behavior indicated a decreased sensitivity to other people

in the presence of a loud noise. Social survey results on the determinants of community and individual annoyance are examined. The review of research on the mental and physical health effects of noise included hospital admissions, community studies, and industrial studies.

Both the psychological characteristics of the situation and the acoustic properties of the sound will determine noise effects. Further, the ability to predict and to control the noise are important factors in the level of noise effects on individuals.

This review would serve as an excellent source of information for anyone beginning an investigation of noise effects on humans.

## 11

Department of the Army (DA), Headquarters. 1982. Environmental Quality: Environmental Protection and Enhancement. Army Regulation 200-1.

This regulation prescribes the general policies, responsibilities, and procedures of the Department of the Army (DA) to protect and preserve the quality of the environment.

The stated goal of the DA environmental program is to

plan, initiate, and carry out all actions and programs to minimize adverse effects on the quality of the human environment without impairing the Army's mission.

The introductory chapter further specifies program objectives and delineates responsibilities for implementation. In addition, a list of established policies for achieving program objectives is given. Notable policies include: (1) Environmental effects are considered in the planning process for proposed projects. (2) Army activities are monitored for compliance with federal, state, and local environmental quality standards. (3) Materials procurement is implemented with consideration for environmental quality issues. (4) When practicable, installation commanders participate in community environmental action programs.

Specifically, chapter 7 of this regulation covers the Army's environmental noise abatement program. The principal program objectives are:

- (1) Assessing noise impacts
- (2) Complying with applicable laws and regulations
- (3) Achieving noise abatement
- (4) Incorporating noise control provisions in materials procurement and facility siting and design

Compatible land use planning is recognized as the primary noise management strategy. The Installation Compatible Use Zone (ICUZ) program implements Army policy in this area. The following summation of the program is offered:

Through the development of zone maps depicting the average day and night sound level (DNL) from military operations, military and civilian planners work to promote adequate buffer zones between noise sources and noise sensitive areas.

In addition, program responsibilities, acoustic standards, applicable noise descriptors, and appropriate assessment procedures are outlined.

This document delineates the regulatory basis for Army noise management program activities.

## 12

DiPolvere, Edward J. 1987. Control and Abatement of Environmental Noise in N.J. In Proceedings of Noise-Con 87. Pp. 531-34. New York, NY: Noise Control Foundation

This short paper outlines the noise management strategy used by the New Jersey Department of Environmental Protection's Office of Noise Control. The approach is based on statewide regulations enacted in 1974 and covers only industrial and commercial stationary sources.

A description of the noise control process is given according to the three major components of the enforcement effort:

- (1) Complaint registration and coordination
- (2) Field Investigations
- (3) Administrative orders - administrative hearings; court orders - court hearings

In addition, a breakdown of the actual enforcement history of Noise Control Office activities through 1981 is shown.

This apparently successful regulatory process has resulted in over \$9 million in compliance expenditures, reduced noise levels (up to 15 dB) in roughly 50 communities, all accomplished by a staff of three.

## 13

Editorial Research Reports. 1980. Noise Control. Editorial Research Reports (February) 22:127-40.

This editorial report reviews the major aspects of noise control. The report briefly describes (1) the effects of noise pollution, (2) noise control regulations, and (3) airport and airline noise.

Psychological and physiological effects from excessive noise pollution range from mild irritability to heart disease. The most common health threat posed by noise is hearing loss. EPA estimates that some 200 million Americans are subjected to noise levels that could permanently damage their hearing.

The editorial states that although hundreds of local antinoise ordinances have been enacted, very few have been actively enforced. The involvement of the federal government began only in the 1970s. The Noise Control Act of 1972 authorized the EPA to (1) regulate the main sources of noise, (2) propose aircraft noise standards, (3) label noisy products, (4) engage in research and dissemination of public information, and (5) coordinate federal noise control efforts. The report examines the Quiet Communities Act of 1978 using Allentown, Pennsylvania, as a case example. Allentown, an industrial city of 110,000 persons, was the first to receive federal help. New York City's noise control program, one of the strictest in the nation, is also reviewed.

A Senate committee report stated that six million people and 900,000 acres of land are exposed to excess aircraft noise levels in this country. The effort to reduce airport noise is shared by the federal, state, and local governments. State and local governments are responsible for zoning areas adjacent to airports. The federal government, specifically the FAA, is primarily responsible for controlling aviation noise. The editorial examines the Federal Aviation Act of 1968 and restrictions on jet aircraft noise.

The editorial examines many of these issues only superficially. However, it is an excellent primer on noise control.

## 14

Eghtesadi, Kh., and G. B. B. Chaplin. 1987. The Cancellation of Repetitive Noise and Vibration by Active Methods. In Proceedings of Noise-Con 87. Pp. 347-52. New York, NY: Noise Control Foundation.

This paper discusses the emergent technology of active noise control. The basic process is described and possible applications are summarized.

Active control is characterized as being poised to enter the marketplace in a variety of major industries. It allows noise and vibration to be effectively cancelled through two basic approaches. The first involves processing the original sound and injecting it back into the sound field in antiphase. The second involves synthesizing the cancelling waveform and emitting it into the sound field.

Some possible applications of active noise attenuation include:

- (1) Auxiliary generators and large compressors
- (2) Repetitive factory machinery noises
- (3) Military equipment operated with greater stealth

- (4) Noise from power company sub-station transformers
- (5) Noise from emergency vehicles such as fire engines
- (6) Exhaust and air intake noise from buses and trucks

An active noise control system is presently best suited for handling repetitive sources of noise. Many applications remain economically infeasible. The power for an antinoise sound must often be equivalent to the power needed for the noise source. New advances in loudspeaker technology offer the promise of reduced implementation costs.

This paper serves as a useful introduction to active noise control.

## 15

Eldred, Kenneth Mck. 1984. Minimizing the Impact of Aircraft Noise Near Airports. In Proceedings, Inter-Noise 84. Pp. 647-52. New York, NY: Noise Control Foundation.

This article discusses the current impact of noise near airports, from both a national and local (airport-specific) viewpoint.

The current national picture is characterized by decreasing aircraft noise and number of people impacted. This change is based on two factors: (1) the replacement or retrofit of older noisier aircraft in accordance with FAA regulations and (2) the implementation of a comprehensive federal planning approach known as the FAA Airport Noise Compatibility Planning Program.

The author discusses some general control measures that can be used alone or in combination at an airport. The following seven controls are identified.

- (1) Flight tracks
- (2) Preferential runways
- (3) Restrict noisy aircraft
- (4) Noise abatement flight procedures
- (5) Shielding barriers
- (6) Soundproofing
- (7) Land use control

Within the compatibility-planning process, the benefits and costs of each control measure must be assessed in relation to the total program.

This short but insightful paper concludes with the argument that an increasing number of quieter aircraft and a solid FAA-supported planning program combine to point the way toward solving airport noise problems.

## 16

Eldred, Kenneth Mck. 1986. Sound Exposure Without Decibels. In Proceedings, Inter-Noise 86. Pp. 111-16. New York, NY: Noise Control Foundation.

This article proposes the use of a linear measure of sound known as sound exposure, as an alternative to the logarithmic measure, the decibel. The measure proposed uses pascal squared seconds, pasques, which are expressed in a day-night sound exposure (DNSE) that is comparable to the day-night sound level (DNL).

A DNSE of one pascal is equal to a DNL of 44.514 dB. Thus, the numbers of importance in the use of DNL, 55, 65 and 75 dB are approximately 10, 100, and 1,000 pasques on the DNSE scale. Of greater consequence is the additive nature of pasques as opposed to the logarithmic nature of decibels. A doubling of operations will result in a doubling of the DNSE while a three decibel increase represents a doubling of the sound level for DNL.

Another strength of the DNSE is that it allows the computation of a single number representation of the population sound exposure. This value can be found by simply summing the population-weighted DNSE over the population affected. This is opposed to the current level weighted population (LWP) which is proportional to the population highly annoyed based on social science surveys. Using the example provided by the author, the LWP for a situation where 2,000 out of 20,000 people or 10 percent are highly annoyed, will equate with a value of 61 dB. If these same people were highly annoyed in an area of 4000 people, or 50 percent, the associated value would be 79 dB. In both, the same number of individuals are impacted but the latter is estimated to be worse. A possible strength of the population weighted DNSE is that relatively more weight is given to populations affected by high noise levels which correlates well with lay conclusions on the desirability of alternative operating scenarios. This is in contrast to the LWP measure.

This article provides a strong argument for the use of sound exposure as an alternative to the decibel. Its additive nature may be less confusing to the public and provide better opportunities for public education.

## 17

Engleman, L. A., and R. Raspet. 1983. Analysis of Legal Precedents and Land Use Controls as Applied to the ICUZ Program. Technical Report N-143, U.S. Army Construction Engineering Research Laboratory, Champaign, IL.

This report describes the legal precedents and land-use controls applicable to the Army's Installation Compatible Use Zone (ICUZ) program. The ICUZ program is designed to protect both the public and the installation's mission by identifying noise-impacted sites around an installation and implementing local land use planning to minimize noise damage.

This 35 page report discusses three applicable U.S. Supreme Court decisions and a number of state court decisions. These decisions establish the basis for pursuing compensation for airport noise-based damages. The authors note that the airport litigation decisions are of particular interest because they have set precedents which may apply to other noise sources. The involvement of the U.S. Air Force in one of these cases may indicate how noise-producing military activities are viewed by a civil court.

The legal theories under which compensation is sought include trespass, inverse condemnation and taking. Briefly, the Courts held that the proprietor of an airport is responsible for damage which occurs to adjacent landowners when the damage is the result of a trespass which is so excessive as to preclude the full use of the land. This excessive trespass, which has been defined as frequent, low flights directly over the property, constitutes a taking of the land without adequate compensation. These decisions further established that between the Federal Aviation Administration, which is the governmental body with congressional authorization to regulate airspace, and the airport proprietor, the proprietor is liable.

The authors then discuss the land use control methods which are available to the Army. Before selecting any method the installation must consider the ability of the local government to enact laws. This authority is given by the state in "enabling legislation" and it differs with each state. The other major consideration is the level of sophistication of the local government structure and the planning agency. The authors consider regulatory controls, public acquisition, incentives for compatible development and installation actions.

Finally an overview of the U. S. Air Force Air Installation Compatible Use Zone (AI-CUZ) program is given. The program has four main goals: (1) to decrease the possibility of an aircraft accident, (2) to prevent incompatible development, (3) to help

local authorities protect and promote the public health, safety and welfare, and (4) to prevent the compromise of an installation's mission.

This report makes a thorough examination of the legal precedents and land-use controls within which the Installation Compatible Use Zone program must work.

## 18

Federal Highway Administration. 1979b. Highway Noise and Compatible Land Use - Fullerton, California Case History No. 1. Washington, DC: U.S. Department of Transportation.

This is the first in a series of monographs providing case examples of highway noise and compatible land use for specific cities in the United States. This case study details the methods employed by Fullerton, California, to cope with highway noise problems.

Because of Fullerton's rapid development in the 1950s and 1960s, by the 1970s, the only land left for development was near the city's major freeway. Instead of banning development or restricting land use type, Fullerton has closely examined development proposals for noise compatibility. This effort is supported by a local ordinance prohibiting exposure of residential developments to high noise levels and a citywide noise contour map. The city monitors and approves noise mitigation elements of a developer's designs and requires the review of interior sound levels before a building permit is issued. The results have been innovative designs such as the use of garages as buffers, locating open space away from the freeway, and the use of berms and creative landscapes as noise easements.

Fullerton is an example of a city whose local ordinance and administrative approach forced innovations by developers to mitigate the noise impacts to residential households.

## 19

Federal Highway Administration. 1979d. Highway Noise and Compatible Land Use - Livonia, Michigan Case History No. 5. Washington, DC: U.S. Department of Transportation.

This is the fifth in a series of case studies describing highway noise and compatible land use for specific cities in the United States. This monograph details the unique land use methods employed by Livonia, Michigan, to cope with highway noise problems.

The city of Livonia first encountered the highway noise problems when after they had selected the location of a new freeway, a parcel of land adjacent to the future freeway was subdivided for single-family residences. Recognizing the unacceptable location of the subdivision, the city created a parkland buffer between the subdivision and the freeway. This "greenbelt" is a requirement for all development near the freeway.

In a few cases, the greenbelt requirement is sometimes supplemented with heavy plantings and low earth berms. The freeway was initially constructed below ground to attenuate noise problems making only small berms necessary.



This case study is an excellent example of land use planning, in the form of greenbelt easements, that can solve visual and noise problems which often impair the marketability of residences located near highways.

## 20

Federal Highway Administration (FHWA). 1974. The Audible Landscape: A Manual for Highway Noise and Land Use. Washington, DC: U.S. Department of Transportation.

This manual presents a wide variety of administrative and physical techniques for coping with highway noise problems, then follows with implementation strategies for the techniques. The purpose of the manual is to provide local governments, architects, developers, and builders with the basic information necessary to achieve noise impact reductions for land uses near highways.

The administrative techniques available to local governments to encourage noise compatible land use control near highways fall into five categories: (1) zoning, (2) legal restrictions such as building and health codes and subdivision laws, (3) municipal control or ownership of the land, (4) financial incentives for compatible uses, and (5) educational and advisory municipal services.

The physical techniques to reduce noise impacts for highways can be grouped into four major categories: (1) acoustical site planning, (2) acoustical architectural design, (3) acoustical construction, and (4) noise barriers.

Finally, the implementation strategies discussed contain several major phases: problem identification, examination and selection of administrative techniques suited to the locality, study of the legal status, study of state legislative changes, and implementation. Six problems that can be encountered when a noise program is implemented are also elaborated on. These include: (1) public apathy, (2) limitations under state laws, (3) financial cost to the municipal government, (4) negative physical and aesthetic side effects, (5) opposition with private interests, and (6) conflicts with local tradition.

The manual provides valuable information for local governments planning noise compatible land uses near local highways. The brief reviews of techniques and strategies are supplemented with case studies and other sources of information to assist local government officials in dealing with the problems of noise sensitive land issues associated with highways.

## 21

Federal Interagency Committee on Urban Noise. 1980. Guidelines for Considering Noise in Land Use Planning and Control. Washington, DC.

This document presents a broad overview of federal agency involvement and guidance in addressing noise/land use issues. It is meant to serve as an aid to local communities for considering noise in land use planning and site review decisions.

Section 1 of the report contains two tables. The first divides noise levels into a set of noise zones according to three commonly used noise descriptors (DNL,  $L_{eq}$ , and NEF). The second table consolidates information from a number of federal agencies to suggest a set of land use compatibility guidelines.

The second section identifies the commonly used techniques for dealing with noise in land use planning. A range of techniques is presented in tabular form which

not only identifies the situations where individual techniques are most applicable, but also comments on how these techniques can be implemented. The effectiveness of any given technique is always a function of the specific noise environment to which it is applied. Often a combination of techniques will provide an effective management strategy.

The third section reviews the noise policies and programs of the federal agencies involved in noise issues. The six agencies are:

- (1) Department of Defense (DOD)
- (2) Department of Housing and Urban Development (HUD)
- (3) Environmental Protection Agency (EPA)
- (4) Department of Transportation/Federal Aviation Administration (DOT/FAA)
- (5) Department of Transportation/Federal Highway Administration (DOT/FHWA)
- (6) Veterans' Administration (VA)

The noise policies of the various agencies differ in the kinds of controls and techniques emphasized, as well as the type and purpose of noise levels used.

The report also includes a set of valuable appendices:

- (1) An explanation of environmental noise descriptors
- (2) A discussion of the health effects of noise
- (3) A bibliography with brief annotations of applicable federal documents and manuals
- (4) A list of federal agency points of contacts

This report remains one of the key references on the general topic of noise management.

## 22

Fidell, Sanford. 1978. Nationwide Urban Noise Survey. Journal of the Acoustical Society of America 64(1):198-206.

This article details a nationwide study commissioned by the U. S. EPA to assess human response to various common noise sources. The study covered a diverse group of lifestyles over a broad range of noise exposure conditions in its analysis of community reactions to noise.

The urban noise survey consisted of respondents from seven major cities at 24 sites. Respondents were chosen from noise exposure ranges centered at  $L_{dn}$  values of 50, 55, 60, 65, 70 and 75 dB. An additional criterion for selection was the population density of the sites. Selection of respondents was made from sites with population densities of 2,000, 6,300, 20,000, and 63,000 people/mi<sup>2</sup>, or roughly proportional to the national distribution. Finally, the sites selected included a geographic distribution of urban areas in the United States.

A questionnaire developed to provide socioeconomic data and direct information concerning specific noise sources and individual annoyance was administered to respondents at each of the 24 sites. The respondents included 762 men and 1,275 women, of whom 670 men and 1,164 women were contacted by telephone. Of the 2,037 respondents, 203 or 10 percent, were interviewed in person.

The results indicated that 31 percent of those annoyed considered themselves highly annoyed. Twenty-two percent thought noise was equally annoying at all times of the day while 22 percent found evening noise and 27 percent found noise at night more annoying. Only 19 percent of the individuals annoyed had ever complained to local officials. Motor vehicles were considered the most annoying noise source, with aircraft noise ranked below people's voices and loud pets.

Regression equations were developed to explain annoyance. The best single predictor was noise exposure measured in  $L_{dn}$  which explained 49 percent of the variance. Population density proved to be a useful surrogate for physical exposure in predicting annoyance. It was the best predictor in a multiple regression equation which also included average annual household income, average duration of residence at site, and average age of site. This equation explained 47.4 percent of the variance. The strongest multiple correlation included speech interference, population density, and if noise affected their health. This accounted for over 90.4 percent of the variance.

This study is extremely valuable because of its nationwide extent, its sampling of a diversified cross-section of the urban population, and the analysis of several ubiquitous noise sources.

## 23

Fidell, S. 1981. The State of the Art of Assessment of Noise Induced Annoyance.

Paper presented at 102nd meeting of the Acoustical Society of America, Miami Beach, FL.

The "business as usual" approach to assessing human response to noise has been to predict annoyance from the measured parameters of acoustic signals. Non-acoustic or "nuisance" variables are believed to intervene in the noise/response relationship, but are explained only as inputs in a behavioral "black box." This paper criticizes the accepted practice and challenges noise researchers to continue to pursue a full understanding of human annoyance to noise; in short, to discover what goes on inside the black box.

One of the underlying assumptions behind the assessment of noise-induced annoyance is that the level of annoyance is proportional to the audibility of the acoustic signal. Thus, A-weighted networks or filters which are geared to human aural sensitivity are commonly the basis for noise metrics. Yet, it has been shown that, "a theoretically based metric of detectability can do a better job of predicting annoyance than A-weighted sound pressure levels." For example, a metric using a bandwidth-corrected signal to noise ratio has been used with success.

Nevertheless, it is argued that the continued pursuit of correlating physical properties of waveforms to levels of annoyance has limited utility. Rather, what is needed is an increased understanding or modeling of what goes on in the black box. As an initial step in this direction, the author offers a model based on the theory of signal detectability. A schematic diagram of its major parts is presented.

The model incorporates both acoustic and non-acoustic inputs from the external world within an internal decision-making framework. the non-acoustic inputs include observable variables (such as expected costs and payoffs for any actions, and a priori information about the likely distribution of signal plus noise within an observation). In addition, the emotional state of the receiver is accounted for in an irritability calculation that affects internal decision making.

The model is offered as a vehicle for testing hypotheses. The paper as a whole is a thought-provoking attempt to encourage a systematic approach to understanding noise-induced annoyance.

## 24

Fields, James M., and Clemans A. Powell. 1987. Community Reactions to Helicopter Noise: Results from an Experimental Study. Journal of Acoustical Society of America 82(2):479-92.

This study explores community reactions to low numbers of helicopter noise events. The objective was to evaluate the metric used to assess helicopter noise exposure in urban areas. A small number of operations (less than 50 per day) raise questions about the assumptions contained in  $L_{eq}$ -based noise indices, concerning the relative effects of maximum noise levels and the number of noise events.

An experimental study design was selected which included a combination of laboratory and social survey techniques. Over 300 community residents were repeatedly interviewed about daily noise annoyance levels over a 22-day period. Noise exposure levels were purposefully controlled over this period. Neither the control over noise levels nor the study focus on military helicopter noise was known by the survey respondents. Although, the focus of the study design was on the effect of acoustical factors on annoyance, demographic and attitudinal factors were also analyzed.

The statistical analysis of the survey results yielded the following findings:

- (1) The effects of both maximum noise level and number of noise events on annoyance were consistent with assumptions in  $L_{eq}$ -based indices. However, it could not be rejected (at the  $p < 0.05$  level) that the number of events has only a small impact on the level of annoyance.
- (2) The effect of the duration of the noise event on annoyance was consistent with the principles contained in  $L_{eq}$ -based indices.
- (3) No significant difference was found in the reactions to impulsive and nonimpulsive helicopter noise after removing the effect of noise event duration.
- (4) The survey responses were not significantly related to differences in demographic characteristics (age, sex, employment status, and military employment).
- (5) The survey responses were related to attitudinal variables (perception of danger to aircraft, beliefs about the preventability of aircraft noise, and feelings about the local area).

This article provides valuable information on the evaluation of noise metrics for helicopter noise, as well as defining the role of nonacoustical factors on annoyance.

## 25

Frankel, Marvin. 1986. Regulating Noise from Illinois Airports. Illinois Business Review 43:3-9.

This article describes the current plans to regulate noise emanating from Illinois airports and assesses some likely impacts. It condenses some of the findings of a 1981 study, Economic Impact of Proposed Noise Regulations, by the Illinois Institute of Natural Resources (subsequently the Department of Energy and Natural Resources).

It was found that 14 out of the more than 100 public airports in Illinois would be in violation of the state's proposed regulations, which are to be phased in between 1988 and 1994. Progressively tighter noise standards will be adopted for the maximum permissible level of noise emissions from public airports to any class A (residential) lands, with a 65  $L_{dn}$  level set for 1994. The  $L_{dn}$  measure used is a weighted day-and-night annual average of noise levels, incorporating a penalty (or decibel addition) for nighttime noise. The core of the noise conflict is identified essentially as a jet noise problem at two Chicago airports (O'Hare and Midway). A summary table shows the 14 airports in violation of the regulations and the estimated total of residential units within designated noise intervals.

Annoyance to noise is defined as a psychological response to a given noise level resulting in speech or sleep interference but potentially arising in a wide variety of circumstances. Any anxiety or apprehension caused by noise is a factor in annoyance, as well as attitude toward the noise. Present research indicates that the airfield noise problem is primarily an annoyance rather than a direct physical health problem. The effects are believed to be principally transient, noncumulative, and without lasting impairments.

The author views the airport noise problem as more complicated than a simple two-party case of transgressors (polluters) and victims. Environmental disamenities such as noise pollution tend to be capitalized into property values; properties burdened by noise are worth less than similar properties without. The value of the affected property can be expected to drop an average of 0.6 percent per decibel of increased noise. Former and current property owners who had their property value discounted are seen as victims. Individuals who purchase or rent property (with knowledge of the noise level) at a discounted value are seen as being effectively compensated for the future noise burden. The complete elimination of an airport (and its noise) may also decrease property values, demonstrating the often symbiotic relationship between airports and local communities.

Five methods of noise abatement are identified.

- (1) Noisy aircraft can be replaced or be retrofitted with quieter engines.
- (2) Operating procedures can be modified.
- (3) Sound-absorbing earthen beams can be used to reduce the impact of engine testing and run-up noise.

- (4) Actions directly involving noise receivers, such as insulating homes or purchasing emission rights, can be taken.
- (5) Airport activity levels can be reduced.

The relative costs of these methods vary widely and are dependent on the conditions at individual airports. Changes in operating procedures can often bring substantial reductions in noise levels at a low cost. Noise emission rights or easement purchases are more costly (from 2 to 17 percent of the property value). Residential noise insulation is costlier yet, and land acquisition tends to be the most expensive method of all. Activity-level cutbacks have complex repercussions that can compromise the air transportation system and are difficult to quantify.

This concise and readable article provides a valuable reference source on the application of economic reasoning to airport noise problems.

## 26

Griffiths, I. D., and G. J. Raw. 1986. Community and Individual Response to Changes in Traffic Noise Exposure. Journal of Sound and Vibration 111(2):209-17.

This article examines whether or not subjective response to noise under conditions of unchanging traffic noise exposure can be used to predict changes in noise levels.

The research involved parallel acoustic and psychological surveys at roadside sites subject to upward or downward changes in noise levels. A survey was conducted before and after the changes in noise exposure.

The six residential locations chosen for the study had to meet the following criteria: (1) at least an expected change of 3 dB(A), (2) at least 25 dwellings of similar types of property exposed to similar before-and-after conditions, and (3) no major source of traffic noise other than road traffic. The survey yielded 469 "before" interviews and 391 "after" interviews. For each household, the 18 hr  $L_{10}$  dB(A) was calculated 1 meter from the house facade and 1.8 meters above the ground. This allowed the development of a regression equation selecting  $L_{10}$  with mean dissatisfaction in the "before" condi-

tion to predict mean dissatisfaction in the "after" condition. This could then be related to the actual survey of "after" dissatisfaction. The equation developed was as follows:

$$\text{mean DS} = 0.113 L_{10} - 2.75$$

where

mean DS = mean level of dissatisfaction

$L_{10}$  refers to the 18 hr  $L_{10}$  dB(A)

$r = 0.529$     $p < 0.001$     $df = 405$

The predicted values from the equation were compared to the actual survey values for mean dissatisfaction using the students *t* test. The null hypothesis that the difference between the two values was zero was rejected.

The findings of this study suggest that greater levels of changes in dissatisfaction occur than will be predicted by data gathered from individuals living in stable acoustical environments. The difficulties between predicted and observed values in the noise level varied considerably by an order of at least 10 dB(A) 18 hr  $L_{10}$ .

This article raises an interesting question, since most studies base changes in dissatisfaction from noise level change on predictive equations from steady-state environments. The policy implications for this study are that noise attenuation measures may vary more in effectiveness than is predicted, if indeed the change in dissatisfaction from noise changes is a long-term effect.

## 27

Helicopter Association International. 1983. Fly Neighborly Guide. Washington, DC.

This guidebook was developed as an aid to helicopter pilots, heliport operators, and managers in the implementation of the Fly Neighborly Program. This voluntary noise reduction program was developed by the Helicopter Association International (HAI) and designed to be implemented worldwide. The guidebook, which is updated periodically, provides an introductory outline of noise reduction measures which can be tailored to meet local conditions.

The Fly Neighborly Program was developed in response to the FAA withdrawal of a proposed noise rule for helicopters in 1981. It was regarded by the helicopter industry as

a voluntary, yet necessary action designed to preclude the eventual implementation of restrictive and mandatory federal, state and local laws, regulations and ordinances.

Until the advent of improved technology, the helicopter industry (both manufacturers and operators) recognizes its responsibility to reduce noise impacts on affected communities. An



active public relations campaign aimed at promoting the image of the helicopter as a transportation alternative is an integral part of the program.

The guide is outlined according to the three distinct but interrelated components of the Fly Neighborly Program (1) training and indoctrination, (2) flight operations planning, and (3) public awareness promotion. The scope and major points for each of these components is discussed. Supplementary materials (i.e. newspaper excerpts, examples of operations procedures, and promotional items) are also included.

This guide illustrates an industry-sponsored attempt to develop a model of self-regulated noise control.

## 28

Hirsch, I. J. 1987. Effects of Noise on People. In Proceedings, Inter-Noise 87. Pp. 977-80. New York, NY: Noise Control Foundation.

This brief article examines the effects of noise on people. Some of the topics considered are noise-induced hearing loss, interference with speech communication, health effects, annoyance, and a brief discussion of predictors of noise.

The development of noise control measures has occurred as a result of the potentially deleterious effects of noise on people. Concerns over the relationship between noise and hearing loss and between noise and interference with speech communication have been the basis for the regulation of maximum permissible noise levels, particularly in the workplace. Research into speech comprehension has shown that speech must be about 6 dB higher than background noise levels. The articulation index (AI) relates speech intelligibility to noise level, frequency spectrum, etc. Health concerns other than hearing loss include blood volume and blood pressure. However, these concerns have not been supported in a recent study involving military personnel. A more extensive literature investigates the health effects of noise-related disturbances to a person's sleep. The meaning, familiarity, and adaptation to noises complicates the understanding of the relationship between sleep and noise level. Annoyance is another effect of noise on people. Annoyance levels are dependent upon the intensity of the noise and the complaint behavior within the community. It is also clear that the frequency of occurrence and duration of the event will partially determine the level of annoyance.

Accurate predictive descriptors are essential for indicating when noise levels are too high and when they have been decreased sufficiently. Unfortunately, the standard frequency-weightings predict differently, depending upon whether one is predicting hearing loss, interference with speech, annoyance or interference with sleep. The author recommends the use of the A-weighting network to best predict multiple effects.

The author covers a wide range of noise related health effects. It is a good introduction to a broad base of existing literature.

## 29

Hitchcock, John, and Alan Waterhouse. 1979. Expressway Noise and Apartment Tenant Response. Environment and Behavior 11(2):251-67.

The purpose of this study was to (1) determine which of a set of possible attributes or factors associated with expressways had an impact on satisfaction of apartment tenants; (2) attempt to assess how important these factors were; and (3) determine the implications these findings might have for land use policies.

Criteria used in selection of the survey sample were building setback (distance from highway) and building orientation (relative to the expressway). There were three setback zones: near (0-50 feet), medium (151-500 feet), and far (501-1,200 feet). The two possible building orientations were perpendicular and parallel to expressway alignment. These criteria lent themselves to a third criterion, screened or unscreened from the expressway. Parallel buildings will have one screened side and one unscreened, while perpendicular units will have two unscreened sides. The final sample consisted of 23 buildings representing 20 combinations of the selected criteria (including expressway accessibility). Seven hundred ninety-five apartment tenants responded to the survey questionnaire.

Almost 60 percent of the sample reported being disturbed or severely disturbed by noise. The article provides detailed results on the level of disturbance from noise for the three setback distances and for unscreened and screened faces. The authors revealed there was evidence of substantial disturbance from the expressway noise. In addition, the authors examined whether expressway accessibility would offset or compensate the noise disadvantage. In conclusion, the authors contend that on the screened side of buildings, noise disturbance was not an overriding factor in their general assessment of the residential environment. Along unscreened building sides, noise is not only a very important factor but also one outweighing any advantage which may accrue from access to the expressway. In view of these points, the authors finally suggest a number of building design principles.

This article shows how behavioral research can help noise control managers in the design of residential apartment units. It provides excellent insight to the many factors on which tenants assess their living environment.

## 30

Job, R. F. S. 1988. Community Response to Noise: A Review of Factors Influencing the Relationship Between Noise Exposure and Reaction. Journal of the Acoustical Society of America 83(3):991-1001.

The objective of this research was to review social survey evidence on the noise/reaction relationship across cultures, computational measures and noise sources. Included in this review was the examination of respondent-related variables such as attitude toward the noise source.

The review covered 39 social surveys conducted in 10 different countries. The surveys examined seven different noise sources and employed a "bewildering array" of noise indices, measurement methods, and scaling techniques for assessing human reaction to noise exposure levels. The results of the surveys are summarized in a table showing: study authors, country, type of noise, sample size, and correlations between noise exposure and reactions for both individual subjects and grouped (community) data.

The review of the surveys demonstrated that "remarkably similar results have been obtained across different nationalities with different measurement techniques." Noise/reaction correlations are significantly stronger for grouped data ( $r = .82 \cdot .14$ ) than for individual data ( $r = .42 \cdot .12$ ). It was also determined that variables such as personal noise sensitivity and attitude toward the noise source, account for a greater proportion of the variation in individual responses to noise than the actual exposure level itself.

The review also established the significance of impulsive noise sources. Notably, there were reduced correlations in the individual data for these sources, which appear to be explained by an increased influence of attitude as a modifying variable.

The article provides an up-to-date synthesis of social survey results on the noise/reaction relationship.

## 31

Kantor, Mark. 1977. The Legal and Institutional Framework for an Airport Noise-Compatibility Land Use Program. Journal of Law Reform 10:447-75.

Like noise reduction and operational adjustments, land use management is a necessary requirement for noise compatible development around airports. This article assesses the constitutional basis for the use of zoning to encourage noise compatible land use and identi-

fies inherent difficulties in establishing an institutional framework for effective land use management. Specific focus is placed on the locus of authority in land use management.

An effective noise compatibility program can pursue either of two zoning approaches: indirectly, through airport hazard zoning, or directly, through airport noise compatibility zoning. The first is likely to be successfully challenged, based on the Fifth Amendment, as taking for public use without just compensation. It is argued that the latter should be able to withstand any Constitutional challenge.

This article is one of the definitive sources on the legalities of noise compatibility zoning in communities located adjacent to airports.

## 32

Knack, Ruth Eckdish, and Jim Schwab. 1986. Learning to Live with Airports. Planning (APA) 52:11-15.

This brief article describes some recent efforts to deal with airport noise problems. Airports are characterized as LULUs, locally unwanted land uses, which require large amounts of land and generate widespread off-site effects. Examples are given of federal, state, and local government, and even private actions, to implement noise abatement plans.

The range of policy options examined include (1) federal financial incentives provided to airports for developing noise abatement plans that are filed with the FAA; (2) a negotiated agreement between airport representatives and local interests over the John Wayne Airport in Newport Beach, California; (3) proactive planning in Clark County, Nevada, to prevent future noise problems around airports (including a military base); (4) the hiring of private aviation consultants by a Fort Wayne, Indiana, business to develop a long-range development plan for an airport area; (6) the attempt to adopt a "noise-budget" at airports in the Minneapolis-St. Paul area; and (7) the enactment of content-specific state zoning regulations in New Jersey.

The authors do not draw specific conclusions concerning the effectiveness of various noise management options. However, individual reference contacts are given for nearly every cited example.

**33**

Landreth, K. 1981. The 1980 Aircraft Noise Act: Noise Abatement or Just More Noise? University of California-Davis Law Review 14:1049-79.

This article reviews judicial, legislative and regulatory responses to aircraft noise, in particular it examines the Aviation Safety and Noise Abatement Act of 1979.

The judicial response to noise from aircraft is described through the analysis of the three Supreme Court cases. The cases of *U.S. v. Causby*, *Griggs v. Allegheny* and *City of Burbank v. Lockheed Air Terminal* are briefly discussed in the first part of the article.

The Aviation Safety and Noise Abatement Act (ASNA) mandated the establishment of a national noise measurement system, provided for the development of local noise compatibility programs, and prescribed the airline industry's role in reducing noise.

The act stresses noise compatibility planning as the primary solution to the noise problem. However, the author notes that the act offers no new planning solution, it merely reiterates recommendations contained in prior legislation and regulations. Many problems exist with the current recommendations. The noise compatibility provisions are deficient with respect to innovation and funding. Zoning is only effective for municipalities that have the authority to establish comprehensive ordinances. Options such as soundproofing are effective only with respect to indoor noise reduction and are generally very expensive.

The most controversial provisions of the act are those which extend waivers for compliance with Federal Air Regulation 36 to two- and three-engine aircraft. The most serious consequence of the waiver provisions is that they impede immediate noise relief.

It is concluded that the ASNA legislation is deficient in regard to both its recommendations and its funding. Further, the Act's division of responsibility for noise abatement between the local and federal agencies does not provide the necessary authority, guidance and funding to ensure the efficacy of planning. Ameliorative legislation to help reduce airport noise is recommended.

The author provides a well-supported critical assessment of the ANSA and federal noise abatement policy.

## 34

Lawrence, A. B. 1984. Transportation Noise Reduction - The Failure of the 1980s. In Proceedings, Inter-Noise 84. Pp. 611-16. New York, NY: Noise Control Foundation.

In this short paper the author argues that the level of transportation noise reduction achieved within the last decade has been a disappointment. A brief examination is made of the management and regulatory approaches used to control aircraft noise, road traffic noise, and railway noise. The examination covers both the U.S. and the EEC.

The proposed management solution to the transportation noise problem consists of three parts: (1) increased emphasis on planning and design, (2) increased use of financial incentives (through the introduction of the polluter pay principle) aimed at

manufacturers and users of noisy vehicles and equipment, and (3) the use of monies collected through noise pollution charges to compensate victims.

This paper presents a thought-provoking critical analysis of efforts to reduce transportation noise within the last decade.

## 35

Luz, G. A., R. Raspet, and P. D. Schomer. 1985. An Analysis of Community Complaints to Army Aircraft and Weapons Noise. In P. D. Schomer and R. D. Neathammer. Community Reaction to Impulsive Noise: A Final 10-Year Research Summary. Technical Report N-167, U.S. Army Construction Engineering Research Laboratory, Champaign, IL.

This paper analyzes noise complaints received by the Army and compares several models for explaining complaint behavior.

A data base of 287 complaints was collected by the U.S. Army Construction Engineering Research Laboratory (CERL). The noise complaints were received by major Army commands over a one-year period between 1979 and 1980. The objectives of the analysis were (1) to determine the nature of the complaint and the type of noise and (2) to determine the relationship between complaints and the day-night average noise level (DNL).

The analysis confirms the utility of the C-weighted DNL rather than the A-weighted DNL as a measure of blast noise at Army bases. The former measures both audible and low-

frequency vibrational energy, while the latter measures only audible energy. Vibration or physical damage or both were mentioned in 77 percent of the blast noise complaints. However, the actual relationship between complaints and noise was weak and challenged the validity of the accepted models of complaint behavior.

The accepted Army model of noise and complaint behavior (the DNL model) has two basic forms. In the first, complaints are seen as a symptom of annoyance, and increases in DNL lead to increases in both annoyance and complaints. In the second, complaints are believed to directly result from annoyance, increases in DNL lead to an increase in annoyance which causes an increase in complaints.

Based on the analysis and the work of Schultz (1978), the authors suggest an alternative model of complaint behavior. Annoyance is seen as a function of both average noise level and average psychological arousal. Complaints are seen as being a function of arousal only and not necessarily correlated with DNL.

Increases in arousal are the input in a behavioral "black box" that leads to complaints. This process is thought to be similar to the concept of dishabituation in behavioral psychology. The authors sum up the process in five basic points:

- (1) People habituate to a broad range of noise levels and will stop responding to noise.
- (2) People unconsciously compare new noises to expectations of the typical level and become aroused if it differs.
- (3) Arousal is an unpleasant state, and some sort of rational action will be pursued to prevent its reoccurrence (a complaint to the Army post).
- (4) If the complaint fails to achieve its goal, increased emotional arousal will result. Eventually, this unpleasant state will begin to extinguish.
- (5) As emotional arousal extinguishes, some other type of directed behavior will be adopted (litigation or political pressure). Individuals may also decide to leave a noise-impacted area.

The authors support a policy which assesses the level of annoyance rather than the number of complaints. Annoyance can exist without complaints, and conversely, complaints may occur without adverse noise levels. The analysis of the time pattern of complaints suggests the importance of effective response to first time complaints.

This paper is an invaluable source of information on the process of complaint behavior triggered by Army aircraft and weapons noise.

**36**

Mabson, W. E. 1975. The USAF Noise Control Program - An Overview. In Proceedings, Noise-Con 75. Pp. 217-21. Washington, DC: National Bureau of Standards.

This paper outlines and discusses the five parts of the U. S. Air Force Noise Control Program.

- (1) Source Reduction: At the present time, the potential for large source noise reduction for strategic and tactical military aircraft does not exist.
- (2) Conservation of Hearing: A comprehensive Air Force internal program to conserve the hearing of all personnel exists.
- (3) Research: Research on aircraft noise reduction is being conducted at the Air Force Aero-Propulsion laboratory, the 6570th Aerospace Medical Research Laboratory, the Flight Dynamics Laboratory, and the Air Force Office of Scientific Research.
- (4) Operational Constraints and Procedures: In an attempt to minimize noise impacts in the immediate environs of air bases, the Air Force employs techniques such as modifications to flight paths, altitudes, climb and descent profiles, and numbers and timing of daily operations. The difficulty to locate training areas where nuisance can be entirely avoided is recognized.
- (5) Land-Use Planning: The Air Force participates in community and land-use planning using the AICUZ (Air Installation Compatible Use Zone) program, in order to delineate land-use districts and guidelines of compatibility for land areas impacted by aircraft operations. The system used for noise description is the day-night average sound level ( $L_{dn}$ ) developed by the EPA. The  $L_{dn}$  also allows evaluation of noise reduction measures.

The conclusions drawn emphasize that there is a potential for military aircraft noise reduction that will be exploited "whenever possible through operational procedures and constraints."

The paper provides a concise review of the USAF noise control program as it existed in the early 1970s.



## 37

Magan, Alan. 1979. Quiet Communities: Minimizing the Effects of Noise through Land Use Controls. National Association of Counties Research, Inc.

This handbook is a basic reference guide to the utilization of land use plans and regulations as one method for controlling noise problems. It focuses on techniques which either block the path of the noise or keep people, and sensitive land uses, away from the noise.

The text discussion is broken into three parts: comprehensive land use planning, implementation techniques, and special noise problems. It is suggested that planning for noise control should be an integral part of the comprehensive planning process in any community. The purpose of the plan is to identify and designate compatible land

uses. It guides local government in developing a desired pattern and density to urban development. Comprehensive planning for noise control includes six basic steps: (1) problem identification and description, (2) policy analysis and formulation, (3) land use plan development, (4) assessment of implementation techniques, (5) choice of implementation techniques, and (6) implementation.

A variety of implementation techniques are discussed individually within two broad categories: zoning and physical techniques. The techniques appropriate for critical noise problems are suggested. The five critical noise issues of concern to local governments are airports, highways, railroads, motorcycles, and industrial noise.

A large percentage of this document is composed of a set of appendices which provide the planner with valuable tools for implementing noise control techniques. Examples include an explanation of how noise is measured and noise levels predicted, a listing of recommended noise standards, a discussion of legal issues, and a bibliography.

This report is a useful introductory guide to the consideration of noise in compatible land use planning.

## 38

Marraccini, Leonard C. 1987. Application of Barrier Theory to Practical Noise Control. In Proceedings of Noise-Con 87. Pp. 295-98. New York, NY: Noise Control Foundation.

This short article examines the theory involving the use of barriers for noise control and applies this theory to specific noise sources to determine the predicted versus the actual noise attenuation capabilities of the barriers.

The theory of barrier noise control involves the mass law and diffraction effects. In mathematical terms, this can be expressed as:

$$TL = 13 + 14.5 \log m$$

where

TL = transmission loss, dB

m = mass per unit area of the barrier, Kg/m<sup>2</sup>

This law is for a finite frequency range. Above this range, the stiffness of the barrier comes into play; below this range, stiffness and resonance come into play. If an assumption is made that the transmission losses of the barrier are sufficient, sound will reach the receiver only by diffraction. In mathematical terms:

$$\text{Atten} = 20 \log [2.5 (2 \div \lambda [A + B - d])]'$$

where

Atten = Attenuation, dB

$\lambda$  = wavelength of sound, m

A + B = shortest path length of the wave traveling over the barrier between the noise source and receiver, m

d = straight line distance from the noise source to the receiver, m

These equations were applied to noise barriers placed on a bulldozer and a track-mounted overburden drill used in coal mining. Noise reduction measurements were made for comparison with the theoretical estimates. Predictions were within 1.5 dB(A) for both sources.

This article documents the effectiveness of noise barriers and provides valuable mathematical formulas for predicting their noise attenuation effects.

## 39

Pavlicek, Michael J. 1982. O'Hare International Airport: Impervious to Proposed State Efforts to Limit Airport Noise. Journal of Law and Commerce 47:413-48.

The author examines the attempts of the state of Illinois and its Illinois Pollution Control Board (IPCB) to regulate noise at O'Hare International Airport.

A full review of the division of responsibility in the area of airport noise is given. The federal government's exclusive jurisdiction over navigable airspace constrains the set of noise abatement options available to the state or any given airport proprietor. The opportunity for noise abatement is limited to control over ground activities at or around airports. However, the relationship between state authority and airport proprietors is complex. Citing applicable case law, it is forwarded that a municipality that

operates an airport (as Chicago does with O'Hare) can have their "proprietary prerogatives influenced" by the governing state. Through a proposal by the Illinois attorney general, the IPCB has ambitiously attempted to influence noise abatement measures used at O'Hare.

An analysis is made of the legal and economic implications of the following list of proposed abatement measures:

- (1) Noise abatement actions that can be directly implemented by the proprietor:
  - Aircraft limitations based on emission characteristics
  - Time limitations for FAR Part 36 noncertified aircraft
  - Curfews
  - Locational or operational changes for ground run-ups
  - Total aircraft limitations
  - Percentage increase in FAR Part 36 aircraft
- (2) Noise abatement activities requiring federal approval:
  - Designated runways for FAR Part 36 noncertified aircraft
  - Preferential runways for all aircraft
  - Shifting operations to other airports
  - Takeoff and landing noise abatement procedures
  - Flight path and approach changes
- (3) Noise abatement actions that are controlled by local zoning authorities

It is concluded that only when a new commercial fleet is fully in place, will noise problems be significantly reduced. The interim measures being proposed would provide only marginal relief, are not economically justifiable, and may subject the IPCB to litigation.

This case study effectively illustrates the immense difficulty of developing "legally valid, technologically feasible, and economically reasonable" state noise abatement regulations at a large international airport.

## 40

Raspet, Richard. 1981. Use of Aqueous Foam to Mitigate Demolitions Noise. Technical Report CERL-TR-N-112, U.S. Army Construction Engineering Research Laboratory, Champaign, IL.

This report describes a study done by the U.S. Army Construction Engineering Research Laboratory (CERL) on the use of aqueous foam in mitigating blast noise produced by artillery, demolition, and explosives ordnance disposal (EOD) activities. The objective was to determine if aqueous foam "is a viable technique for quieting unconfined explosives and to establish design parameters for its use."

The study methodology consisted of six basic steps:

- (1) Literature and telephone search.
- (2) Experiments to assess the level of blast noise reduction caused by aqueous foam.
- (3) Experiments to determine the relationship between the amount of foam used and the reduction in flat-weighted sound exposure level (FSEL), C-weighted sound exposure level (CSEL), and peak sound level. The experiments were conducted using both high- and low-expansion ratios (the ratio of foam volume to fluid volume).
- (4) Development of a set of recommended design parameters.
- (5) Experiments to compare the effectiveness of foam in quieting shaped and cratering charges versus bare charges above the ground.
- (6) Experiments to assess the effectiveness of foam in quieting artillery.

In turn, there were five major findings produced by the study:

- (1) Using both high- and low-expansion ratios, foams can reduce the blast noise of explosive charges by up to 14 dB for unconfined explosions, and an additional 3 to 6 dB for confined explosions.
- (2) The relationship between the level of blast noise reduction and different foams, foam depths, and charge masses could be predicted for both confined and unconfined charges.
- (3) Aqueous foam also reduced the blast noise level of shaped charges and artillery.

- (4) Noise level reductions increase as the amount of confinement increases.
- (5) Plastic bags can be used to increase foam density.

The study presents an in-depth examination of the effectiveness of mitigating blast noise with aqueous foam.

## 41

Rouse, Joseph. 1986. Handling Overflight and Artillery Firing Claims. The Army Lawyer DA PAM 27-50-168:60-63.

This article stresses the importance of considering private property and personal rights by military officials in regard to the planning of training activities involving noise problems such as firing and flying.

In 1942 the Military Claims Act (MCA) was enacted which established the authority to pay for property damages as a result of firing activities. The act does not necessitate the proof of negligence but only the need to determine causation and damages. Suits alleging a negligent act are filed under the Federal Tort Claims Act (FTCA). Negligence is often difficult to prove, since the activity in question consists of a normal military operation conducted and based on military needs not compatible with any civilian standards.

Many cases attempt to prove a taking of property under the Fifth Amendment. These claims are usually filed under the Tucker Act. The United States v. Causby and Griggs v. Allegheny County are two Supreme Court cases involving repeated low flyovers.

To avoid litigation and conflicts, the base commander should use the same guiding principle used by federal judges in deciding cases against the military. The federal judge must determine whether the Army can carry out its mission without infringing on the rights of others. Several cases, Barroll v. United States, Maynard v. United States, and Leavell v. United States were decided in favor of the United States based on this principle.

Instances where this principle was not adhered to involved B-52s flying below necessary altitudes for a mission (Peterson v. United States), and the excessive use of explosives to blow up a bridge in a training mission, (Lakeland R-3 School District v. United States).

Preventive measures are recommended as the first line of defense in the prevention of noise litigation, followed by the institution of a complaint response system. Each installation with regular firing or flying activities is advised to designate an office to receive complaints with a telephone line dedicated for that purpose. The exact hour, date, and location of the disturbance should be documented for later reference.

The author recommends careful preplanning approved by the base commander and the institution of a complaint response system. Sample cases that were won and lost by the United States against private citizens concerning noise problems are described, and potential solutions and valuable contacts for reducing the claims against the military concerning noise are provided.

The article provides an insightful perspective on the claims against the military concerning noise problems and offers useful suggestions for their curtailment.

## 42

Samuels, Marjorie Rachelson. 1981. Hear No Evil: The Effect of High-Intensity Aircraft Noise. Environmental Comment (September):10-13.

This article examines the effects of high-intensity aircraft noise on human health. A brief discussion on the use of receiver controls in airport vicinities is included. A variety of facts and research findings are assimilated to support the case that noise is not just bothersome but also harmful to human health.

Continued exposure to loud volumes of noise can cause irreversible damage to the ear, particularly the cochlea (a sensitive structure in the inner ear). However, hearing impairment or loss is only one of the possible human reactions to noise, and a table of likely responses to common noise levels is provided. The list of possible physiological effects of noise includes (1) increased cholesterol levels, (2) raised blood sugar, (3) vasoconstrictor reflex in the body, (4) dilation of blood vessels in the head, (5) dilation of the pupils, (6) changes in the secretions of the stomach acids and endocrine hormones, and (8) altered functioning of the kidneys. In addition, a noise can affect nerves and emotions (i.e. triggering seizures and causing autonomic stress reactions). Finally, the stress on pregnant women repeatedly exposed to jet noise may cause a high incidence of birth defects.

While the evidence provided is not definitive, the author identifies the range of potential health impacts that high-intensity aircraft noise can have on humans and calls attention to the need for more research.

## 43

Schomer, P. D. 1985. Assessment of Community Response to Impulsive Noise. Journal of the Acoustical Society of America 77(2):520-35.

The purpose of this paper is to examine the assessment of community response to impulsive noise generated by such sources as artillery or helicopters as compared to less unusual sources such as fixed-wing aircraft, street traffic and children.

The surveys which are discussed in the paper were done in communities around two Army installations, Ft. Lewis, Washington and Fort Bragg, North Carolina. The survey instrument was a questionnaire which allowed respondents to rate themselves to be (1) not at all annoyed, (2) slightly annoyed, (3) moderately annoyed, (4) very much annoyed, or (5) extremely annoyed. C-weighted day-night average sound level (CDNL) noise zones were generated based on activities such as armor and artillery fire. Random survey sampling was done within the various noise strata. The noise surveys considered five noise source categories: (1) artillery, (2) airplanes, (3) helicopters, (4) street traffic, and (5) children and/or pets. For each category, the data were arranged by loudness, frequency of occurrence and percentage of respondents "highly annoyed."

The results of these studies indicated that an energy equivalent type of model such as the CDNL is the best available descriptor for community response to impulse noise generated by large Army weapons. Growth in annoyance increased among the local community members monotonically with both sound amplitude and frequency of occurrence. It was further recommended that a nighttime adjustment of 10 decibels be made to the descriptor.

The article provides a detailed examination of the use of the CDNL as a descriptor for assessing community response to impulsive noise and thoroughly documents the findings of the studies involved.

## 44

Schomer, P. D. 1978. Human Response to Noise Vibrations Caused by Sonic Booms or Air Blasts. Journal of the Acoustical Society of America 64(1):328-30.

This letter investigates the response of humans to airborne, large-amplitude impulse noise. The author indicates that direct perception of vibration does not elicit as much of a response from humans as does the reaction to the impulse noise itself and to the noise generated from vibrating surfaces.

Four sets of data were examined in this letter. They include studies on human sensitivity to vibration, studies of complaints dealing with vibration in the Toronto area, studies at Edwards Air Force Base, and general studies on human response to sonic booms.

These studies indicated that although many complaints referred to vibration, the direct vibrations were not what had caused the complaints but rather the rattling of windows and bric-a-brac. The author cites these studies as support for his conclusion that humans respond to the secondary noise radiated by vibrating surfaces and to the noise itself rather than the actual vibrations.

The author gives a concise review of the studies referred to and supports his letter well.

## 45

Schomer, P. D., and R. D. Neathammer. 1985a. Community Reaction to Impulsive Noise: A Final 10-Year Research Summary. Technical Report N-167, U.S. Army Construction Engineering Research Laboratory, Champaign, IL.

This report contains the results of over 10 years of research conducted by the U.S. Army Corps of Engineers' Construction Engineering Research Laboratory (CERL). The focus of the research has been on the assessment of individual and community response to impulsive noise. As a whole, the research results serve as the primary foundation for the community annoyance criteria used in the Army's Installation Compatible Use Zone (ICUZ) program.

From the "confusing array" of noise descriptors available, the A-weighted day-night average sound level (ADNL) has emerged as the standard for assessing responses to transportation noise sources. The problem is that many of the Army's noise sources are impulsive in nature and:

do not readily fit in the context of the sources studied during the past 30 years which led to the development of the ADNL measure.

In addition, the Army's concern with community responses to impulsive noise sources (armor, artillery, demolitions, helicopters, small arms fire) has risen with increasing urban growth near installations. A clear understanding of community responses to impulsive noise was a prerequisite to the development of the ICUZ program.

The report contains eight separate papers based on both laboratory studies and attitudinal surveys of community responses to noise dose levels. The major conclusions of the research are listed as:



- (1) An energy type of model such as the C-weighted day-night average sound level (CDNL) is the best available descriptor for community response.
- (2) Complaints are not a good measure of community response.
- (3) The exact function for relating the percentage of a community highly annoyed to CDNL remains a question.

An appendix is included which presents a 1981 report by the National Academy of Science Committee on Hearing, Bioacoustics, and Biomechanics (CHABA) concerning community responses to high-energy impulse noises. It should also be noted that the eight papers have been published separately in scientifically refereed journals.

The report provides a valuable compilation of current information on the dose/response relationship for impulsive noises.

## 46

Schultz, Theodore J. 1978. Synthesis of Social Surveys on Noise Annoyance. Journal of Acoustical Society of America 64(2):377-405.

This rather detailed article reviews data from over 18 social surveys concerning the noise from aircraft, street and expressway traffic, and railroad sources. The various survey noise ratings were translated into day-night average sound levels ( $L_{dn}$ ). The main objective was to use the survey data to predict community annoyance owing to transportation noise of all kinds.

The author, first, critically reviews the procedures used in the social surveys spanning a period of 14 years and a range of nine countries. Issues concerning correlation between noise exposure and subject response, annoyance scales, intervening nonacoustical variables, and percent "highly annoyed" are all examined in detail. After reviewing these issues, the author concludes that the common "median response" or "degree of annoyance" of the community used in many social surveys is not very useful for planning and monitoring (regulatory purposes). Therefore, the percentage of the population which is "highly annoyed," plotted against some measure of noise exposure, is proposed as a more useful indication of acceptable community noise exposure.

The problem, however, lies in who is to be counted as "highly annoyed." At first, the author used arbitrary judgments as to the thresholds of high annoyance on the different scales. Because of severe criticisms, the author attempted to use an unbiased count of the percent highly annoyed. Examining the results of 11 clustered surveys showed that both the subjective and unbiased measurements of the percentage highly annoyed correlated well with

the measurements of  $L_{dn}$ . Yet, the author preferred to use his original subjective measurement because of the wide differences in the survey measurement scales.

An average curve (in logarithmic form) was fitted to the 11 clustered survey data points for predictive purposes. The original set of clustering survey curves lies within  $\pm 4$  percentage points of their average; and 90 percent of all the data points lie within  $\pm 10$  percentage points of the average.

Finally, the article presents reasons for the data scatter and examines disturbance of various activities by noise. In conclusion, the author states it is not possible to base the decision on what constitutes a community noise level suitable for a living environment on the human response to noise alone. One must also take reasonable account of the ambient noise that already exists in the community.

This seminal article provides some interesting findings on comparability of different social surveys on transportation noise and community response. The author makes no assertions that this synthesis is definitive, rather more research is believed to be needed in this area. The article would be very useful to noise managers wishing to examine the pitfalls, and possible solutions, of social surveys dealing with noise.

## 47

Setter, David M. 1980-81. Highway Noise: To Compensate or Not to Compensate. Drake Law Review 30:144-71.

This article addresses some of the approaches available to those seeking relief for damages resulting from highway noise.

The resolution of the question of whether compensation for highway noise can be obtained must be weighed against the needs of the public in terms of highways as a necessity. Recovery for highway noise must be either completely uncompensable or subject to strict limitations. The author notes that many courts have relied on the premise that extending compensation to landowners adjacent to public highways would open a "Pandora's box" of multiple claims, and have denied it. However, there are several avenues of redress for injury caused by highway noise.

The most effective of these relies on the legal concept of eminent domain. Eminent domain is founded in the Fifth Amendment of the U.S. Constitution, and in many state constitutions, and allows the state to take private property for public use. This taking is limited by the requirement that just compensation be made to the owner of the property. In some jurisdictions (24 states), the compensation is limited to property "taken" for public

use, while in the remaining 26 states, compensation is allowed for property "taken or damaged." In the "taking" jurisdictions, if no part of the land is actually taken or made uninhabitable by the highway noise, compensation will not be available to the landowner. A decrease in market value can in some cases be ruled a partial taking, and some relief may be available.

In the "damage" jurisdictions, a showing of special damages may also account for some compensation for the landowner. However, there is a distinct lack of uniformity in these cases, and a showing of damages is problematic.

Other actions that can be taken exist within tort law. A trespass action has proved ineffective because of a lack of an actual physical invasion of the property. A more reasonable application of tort theory is a nuisance action. This too, however, may prove inadequate because of the governmental immunity that may apply in some tort cases.

The author noted that whether any compensation can be obtained depended largely on what state the claim was made in. Overall this article is well written and understandable to a non-lawyer.

## 48

Singley, John. 1986. Ft. McClellan ICUZ Program: In-Progress Review. Project Report prepared for the U.S. Army Training and Doctrine Command. Fort Belvoir, VA: U.S. Army Corps of Engineers, Institute for Water Resources.

This report presents an in-progress review of the Installation Compatible Use Zone (ICUZ) program at Fort McClellan, Alabama. The review was conducted by the U.S. Army Corps of Engineers' Institute for Water Resources (IWR) and prepared for Training and Doctrine Command (TRADOC) in the spring of 1986.

The objectives of the ICUZ process are to "identify and mitigate noise impacts and problems on installations and in surrounding communities." A community involvement component was developed by TRADOC and IWR in order to best achieve the ICUZ program objectives. This investigation into the Fort McClellan experience consisted of (1) interviews with ICUZ committee members, (2) examination of the Office of Environmental Management's files, and (3) the review of relevant reports.

The ICUZ study process at Fort McClellan was stalled after the development of the noise contours, as the installation was unable to involve any of the surrounding communities. The initial request for support in early 1985 was not responded to, and the installation delayed in renewing its efforts to involve the communities.

The investigation identified a local view which included (1) denial of a problem and tolerance of the noise and its associated benefits, (2) distaste for land use controls and the planning process, and (3) distrust of the noise data which had failed to keep pace with changing installation activities. This was the perception of the local communities' viewpoint that was accepted by command personnel at Fort McClellan.

The ICUZ committee itself was hampered by the lack of (1) effective leadership, (2) proper representation, (3) membership continuity, and (4) regular interaction. In addition, the shortcomings of the noise contour data and the local planning structure resulted in committee inaction.

Several important lessons can be learned from the Fort McClellan experience, the foremost being that the lack of careful planning and preparation may defeat the ICUZ process. The need for careful attention to the proper use of noise data in a community involvement program is also a valuable lesson. Noise zones reflect probability distributions of annoyance, and the pattern of change for a zone emerges as being more important than the exact location of a noise contour. Finally, an effective ICUZ program must be recognized as an ongoing process rather than just the development of the study report as an end product.

This report provides an insightful look into the workings of an actual ICUZ study process. There are several valuable appendices including a complete description of the ICUZ program's community involvement component and the actual Fort McClellan community involvement plan.

## 49

Soenksen, Mary Jo. 1982. Airports: Full of Sound and Fury and Conflicting Legal Views. Transportation Law Journal 12:325-42

This article examines the relevant federal regulations promulgated to control noise as they pertain to aircraft and airspace use. The three theories of relief (trespass, nuisance, and inverse condemnation) used by individuals affected by aircraft are examined and illustrated with specific case studies. Additionally, the issue of federal preemption as it applies to local police powers and airport proprietors in regulating airport noise is addressed.

Basically, there are three federal statutes dealing with airspace, aircraft, and airport noise regulation. They are the Federal Aviation Act of 1958, the Noise Abatement Amendments of 1968, and the Noise Control Act of 1972.

The Federal Aviation Act gives the FAA the power to regulate the nation's navigable airspace, while the 1968 amendments exist "to afford present and future relief and protec-

tion to the public from unnecessary aircraft noise and sonic boom . . .” In November of 1969, FAR 36 (Federal Aviation Regulations Part 36) established noise emission limits for large aircraft of new design and adopted a uniform system for measuring aircraft emissions. This was later supplemented by the Air Carrier Action Plan which is part of the Aviation Noise Abatement Policy of 1976 that addressed FAR 36 compliance and retrofit financing of older aircraft.

Finally, the Noise Control Act of 1972 developed an arrangement between the EPA and the FAA by which the EPA conducted a nine-month study of the FAA noise regulatory program because of what was perceived at the time as “foot dragging” by the FAA.

Besides the federal regulations controlling aircraft noise, three avenues for recovery of noise damages are used by property owners: (1) trespass, (2) inverse condemnation, and (3) nuisance.

The case of the *United States v. Causby* dealt with the action of a landowner whose property was directly below the landing and takeoff path of military aircraft. The Court found that Causby’s poultry business was disrupted, and although the navigable airspace was in public domain, these flights were not within navigable airspace and were in essence an invasion of the surface.

Inverse condemnation was used in *Griggs v. Allegheny County*. Planes passed within 30 feet of Griggs’ residence on takeoff, which was ruled as an unconstitutional “taking” of an air easement by the county without market compensation. The use of inverse condemnation has primarily allowed recovery only to those property owners directly below the flight path.

Finally, the theory used to seek relief from substantial unreasonable interference is the nuisance theory. In *Brooks v. Patterson*, citizens attempted to prohibit planes from flying less than 500 feet above their property, making it impossible to takeoff or land. The Florida Supreme Court stated “the individual, although harassed, annoyed, and subjected to inconvenience, cannot stand in the way of progress but must yield to the . . . greatest good for the greatest number.”

A combination of nuisance and inverse condemnation theories involves *Thornburg v. Portland and Martin v. Port of Seattle*. Both cases against the cities were won based on the decision that a nuisance, whether close by or directly over a plaintiff’s property, amounts to a “taking.” The recovery is measured by the decreased market value of the property.

A landmark case dealing with the concept of preemptions is known as the *Burbank* case. The city of Burbank attempted to ban jet takeoffs between 11 P.M. and 7 A.M. The Court concluded that the FAA in conjunction with the EPA has full control over aircraft noise preempting state and local control. In cases where the municipality is the proprietor

and preemption is not assumed on a case-by-case basis, the courts determine if a regulation is reasonable, nondiscriminatory, and not unduly burdensome to interstate commerce.

The article provides an excellent review of key federal regulations and legal case studies pertaining to aircraft noise.

## 50

Staiano, Michael A. 1986. OSHA Noise Exposure Due to Intermittent Noise Sources. Sound and Vibration (May): 18-21.

The author describes the use of a probabilistic procedure to evaluate the noise control benefits from a set of intermittently operating noise sources.

Given the need for estimating current OSHA noise exposure standards in the workplace, a method must be developed for estimating the contribution of various noise sources functioning intermittently over a given time period. The author tests his computer-aided probabilistic technique for estimating the time-weighted average (TWA) noise descriptor in a sawmill noise control project. The procedure proved effective when compared to actual noise measurements taken at the site. It was useful in identifying the decibel benefits of implementing controls for alternative noise sources.

This study provides insights into how the choice of a noise metric and more specifically its measurement procedure, may affect the selection of optimal noise control measures at a fixed facility.

## 51

Sugden, Robert. 1979. The Measurement of Consumers' Surplus in Practical Cost-Benefit Analysis. Applied Economics 11:139-46.

The author discusses a practical method of calculating the effect of noise pollution on residential areas through changes in consumer surplus in a cost-benefit analysis.

Changes in the level of noise pollution in residential areas can have an effect on property values of the affected homes. In economic terms, there are two relevant goods, noisy houses and quiet houses. A change in noise levels such as the building of an airport can increase the supply of one good and decrease the other. The author assumes the Marshallian framework of partial equilibrium to evaluate the net change in consumer surplus. Based on a

number of assumptions, an equation that can be used to calculate the net change in consumer surplus for houses exposed to noise is as follows:

$$\sum_{i=1}^n (P_1' + P_1'') (X_1'' - X_1')/2$$

where

$P_1'$  = the price of tenancy if nuisance is not undertaken

$P_1''$  = the price of tenancy if the nuisance is undertaken

$X_1'$  = the number of houses in a class or nuisance level if project is not undertaken

$X_1''$  = the number of houses in a class or nuisance level if project is undertaken

The author assumes a linear demand and disregards the reciprocal nature of the noise source and receiver. The noise source may decrease property value owing to a nuisance, yet increase them because of the convenience of transportation and facilities, such as with an airport. Additionally, many economists would argue that ignoring income effects due to property value changes and the generally oversimplistic nature of the approach used make this article useful only in generalizing the effect of noise pollution on residential property values.

## 52

Thunder, Thomas D., and James E. Lankford. 1985. An Easy-to-Use Diagram of OSHA's Noise Exposure Regulation. Sound and Vibration 19(2):24-8.

In this article, the authors demonstrate the use of the Warnier-Orr diagram method to clearly reveal the underlying structure and important relationships in OSHA noise exposure to regulation.

The Hearing Conservation Amendment of 1983 to the Occupational Safety and Health Act of 1970 gave final legal definition to the requirements for an effective hearing conservation program. Subsequent responses have held that the regulations were too complex and restrictive. The inability to understand the regulations has decreased the probability of full compliance in the workplace.

The Warnier-Orr diagram is described as a kind of "super-flowchart." It is composed of four basic constructs: hierarchy, sequence, repetition, and alteration. Previous application of the methodology has primarily been in the areas of computer science and mathematical set theory.

The Warnier-Orr diagram provides the reader with a structured explanation of OSHA noise exposure regulation in the workplace.

## 53

U.S. Department of Defense (DOD). 1978. Environmental Protection: Planning in the Noise Environment. AFM 19-10, TM 5-803-2, NAVPAC P-970. Washington, DC: Departments of the Air Force, the Army, and the Navy.

This manual provides information on the various aspects of noise whose understanding is essential for the development of acceptable noise environments on and near military installations.

The manual begins with a useful overview of the noise environment, which should prove valuable to individuals new to the noise field. This is followed by a chapter on the characteristics and measurement of noise. The basic concepts of the decibel scale are covered, and simple rules for adding the logarithmic measure are provided. The basic noise measures, the A-weighted sound level (AL), the perceived noise level (PNL), the tone-corrected perceived noise level (PNLT), and the C-weighted noise level (CL) are covered.

The A-weighted sound level closely approximates the response of the human ear and therefore de-emphasizes the low-frequency portion of the spectrum. The C-weighted sound level is mainly used for impulse noise such as sonic booms, blasts, and artillery fire.

Besides these basic noise measures, noise descriptors accounting for temporal considerations and cumulative effects are covered. Temporal measures include the sound exposure level (DEL), effective perceived noise level (EPNL), and C-weighted sound exposure level (SEL<sub>c</sub>). Cumulative noise measurements are the composite noise rating (CNR), noise exposure forecast (NEF), community noise equivalent level (CNEL), equivalent noise level (L<sub>eq</sub>), day-night average sound level (L<sub>dn</sub>), C-weighted equivalent sound level (LC<sub>eq</sub>), and the C-weighted day-night average sound level (LC<sub>dn</sub>).

Once the noise measures are explained, techniques to assess the noise contribution for fixed and rotary-wing aircraft, impulse noise, motor vehicle noise, railroad noise, and fixed



source noise are outlined. Each source varies in its noise descriptors and assessment techniques, all of which are described in this section.

After assessment techniques are provided, noise level recommendations are made. Levels must be established, since noise can psychologically and physiologically impact exposed individuals. Most of the levels are based on social science research from 55 community noise case histories. These studies revealed no reaction at 55  $L_{dn}$  by the public; but at 65  $L_{dn}$ , widespread complaints or single threats of legal action occurred. The predominant result of social surveys is that for a given noise level, individual responses vary widely. This variance can be reduced when individuals are considered, based on similar attitudes about "fear of aircraft crashes" and the misfeasance of authorities. Average responses of the whole survey population produce nearly identical results among studies. An additional finding is that not everyone annoyed will complain. At 65  $L_{dn}$ , over 30 percent of the population will be annoyed, but only five percent can be expected to complain.

The reduction of noise conflicts requires the use of noise abatement strategies. One method is noise reduction at the source. Strategies for this fall under three categories:

- (1) Technological change: A design modification which actually reduces the amount of noise from a source.
- (2) Operational change: A change in the operation of the source which may not reduce the absolute level of the noise but reduces the level perceived by the receivers.
- (3) Locational change: A separation of source and receiver which will reduce noise levels perceived but not the level created.

Examples of abatement methods are the use of barriers, changes in takeoff procedures for aircraft, changes in routing and scheduling, the design of quieter equipment, and public relations. A whole host of options are available, all which slightly differ depending on the noise source. The manual outlines possible options for noise abatement of various noise sources common to the military. The noise reduction potential of each measure and the potential cost of implementation are detailed for each noise source.

Finally, the manual provides noise-planning strategies and their applications for military installation. The collection and use of data concerning land use, economics, environmental, and receiver data are outlined, followed by methods to identify impacted areas and, then, implementing solutions in the form of noise abatement strategies.

Overall, this manual is extremely useful for military planners and installation commanders. It outlines basic concepts and "rules of thumb" for noise measurement and briefly outlines possible conflicts and abatement strategies. Detailed technical information for each noise source is not provided, since each source could fill a manual itself. However, a useful review is provided for each noise source common to the military. In general, this manual is an excellent source for reference concerning noise planning.

## 54

U.S. Department of Housing and Urban Development (HUD). 1985. The Noise Guidebook. Washington, DC: GPO

This guidebook is a compilation of various reports, informational papers, and other items to be used as a basic reference document for implementing the noise policies of the Department of Housing and Urban Development.

Nearly half of the U.S. population is regularly exposed to noise levels that interfere with normal activities, and one in 10 suffers a permanent reduction in his or her hearing. The major federal legislation related to controlling noise problems includes the Noise Control Act of 1972; the Quiet Communities Act of 1978; the Federal Highway Act of 1970; and the Aviation Safety and Noise Abatement Act of 1979. HUD's initial involvement with the noise problem stems from the Housing Act of 1949 (Public Law 81-171) which sets forth the national goal of "a decent home and suitable living environment for every American family." The basic foundation for the HUD noise program is the noise regulation 24 CFR 51B. This regulation establishes standards, assigns implementation responsibilities, describes review and approval procedures, and identifies special situations which may warrant waivers of procedures or standards.

The noise descriptor employed by HUD, in addition to the EPA, DOD, and the FAA is called the day-night average sound level (DNL), expressed in mathematical symbols as  $L_{dn}$ . This measure is the 24-hour average sound level expressed in decibels with a 10 decibel penalty for noise between 10 P.M. and 7 A.M.

Using the  $L_{dn}$  noise descriptor, noise levels at a particular site are classified as either acceptable, normally unacceptable, or unacceptable. Noise levels below 65  $L_{dn}$  are acceptable and require no noise attenuation measures, while levels between 65 and 75  $L_{dn}$  at a site are normally unacceptable and require special provisions for siting. Sound levels over 75  $L_{dn}$  are deemed unacceptable and require an Environmental Impact Statement and the approval of the Assistant Secretary of Community Planning and Development.

Interior noise levels are not allowed to exceed 45  $L_{dn}$  as established by the noise regulation 24 CFR 51B. An assumption for this standard is that standard home construction provides 20  $L_{dn}$  of noise attenuation, which would comply with the exterior acceptable standard of 65  $L_{dn}$ .

Compliance with these standards can require acoustical site planning which includes such actions as increasing the distance between the noise source and noise receiver, utilizing noise compatible land uses such as parking lots and maintenance

facilities, locating barrier-type buildings parallel to the noise source, and orienting residences away from the noise source. Acoustic construction techniques for additional noise attenuation can also be used separately or in conjunction with acoustical site planning.

Before the siting of housing areas can be made, an assessment of the noise environment is necessary. Guidelines for the assessment of railway, aircraft, and highway noise as they apply to residential households are outlined, and a section on sample calculations for site assessments is provided.

This guidebook is a valuable reference document for the implementation of HUD's noise policies. Additionally, the basic background materials provided are useful to anyone, especially the "learner," in the noise field.

## 55

U.S. Environmental Protection Agency. 1979. Noise Control Program: Progress to Date. Office of Noise Abatement and Control. Washington, DC: U.S. Environmental Protection Agency.

This document describes the activities of EPA's Office of Noise Abatement and Control (ONAC) in implementing the Noise Control Act of 1972, and the Quiet Communities Act of 1978.

The EPA noise program was originally established under the Clean Air Act Amendments of 1970. Investigations conducted in this initial program provided the support for passage of the Noise Control Act of 1972. Under the act, EPA's role included:

- (1) Identifying major noise sources
- (2) Regulating noise sources
- (3) Proposing aircraft noise standards to the FAA
- (4) Labelling noisy products
- (5) Engaging in research
- (6) Providing technical assistance
- (7) Disseminating public information
- (8) Coordinating federal efforts

The Quiet Communities Act amended the Noise Control Act by expanding the EPA's role in providing technical assistance and disseminating public information. A need was seen for augmenting federal noise source regulations with increased state and local effort in developing effective noise controls programs.

Under the Quiet Communities Act, the EPA was mandated to:

- (1) Establish regional technical assistance centers
- (2) Provide staffing and training assistance to state and local programs
- (3) Conduct a national environmental noise assessment
- (4) Develop educational materials
- (5) Loan equipment to states and localities
- (6) Promote increased noise research

In addition, the EPA was to provide direct financial assistance to states and localities for such items as transportation noise abatement and the evaluation and demonstration of noise control techniques.

EPA efforts in developing noise control programs have been drastically reduced in recent years. This report details EPA activities at the height of its involvement in noise management. A listing of important EPA documents on noise is also provided.

## 56

U. S. General Accounting Office (GAO). 1979. DOD's Commendable Initial Efforts to Solve Land Use Problems around Airfields. Logistics and Communications Division. Washington, DC: GPO.

The purpose of this report was to evaluate the effectiveness of the DOD's Air Installation Compatible Use Zones (AICUZ) program. The program was first initiated in 1973 in an attempt to foster compatible land use around military air bases.

An examination was made of DOD's policies and instructions for its AICUZ program. In addition, 11 airfields (two Army, five Navy, and four Air Force) were visited, with specific programs reviewed and interviews conducted. Primary focus is given to the Navy (including Marine Corps) and Air Force bases. At that time, the Army did not have an active AICUZ program. Its smaller aircraft posed less of a noise problem.

The objective of the AICUZ program is to maintain the operational capability of each military air base while protecting the military and the public from noise hazards. The program was found to be making commendable initial strides toward fostering land use planning around air bases. It was recognized that successful planning requires cooperation from the local communities.

All the bases visited had taken some measures to mitigate the noise problem, such as:

- (1) Modifying approach procedures
- (2) Reducing climb speeds
- (3) Restricting afterburner use
- (4) Eliminating night operations
- (5) Changing flight patterns
- (6) Limiting the number of aircraft in training patterns
- (7) Acquiring acoustical enclosures, noise suppressors, and engine test cells
- (8) Relocating engine run-up stands
- (9) Curtailing night engine run-ups

The various bases had also made efforts to communicate and cooperate with local communities in the land use planning process, including:

- (1) Maintaining complaint logs
- (2) Advocating truth-in-sales notices to home buyers in noise-impacted areas
- (3) Presenting the base's position at zoning and development hearings
- (4) Promoting overlay zoning (using noise contour maps) to achieve compatible development
- (5) Working with federal, state, county, and city agencies to draft state support zoning legislation

Land acquisition was also found to be a prominent noise management tool, with the Navy and Air Force practicing different approaches. The Navy showed greater reliance on local government control of land use both inside and outside of the clear zone (high potential for accidents). Some land purchases were made, or easements acquired, in noise zones where encroaching development threatened. The Air Force had a more active acquisition program, but only for clear zone land rights and easements. In general, the Navy bases were situated in more heavily populated areas with higher property values.

Perhaps the most valuable insight of this report is the distinction that is drawn between Navy and Air Force policies on when and how much land to acquire. The decision is seen as an administrative judgment that balances the risk of dependence on local control of land use and the costs of purchasing land or land rights.

An explanation of Navy and Air Force accident potential zones is included, along with maps showing the effect of operational changes on noise contours. A summary table of all land interests acquired or planned by selected bases is provided.

The report is a primary source of information on early DOD efforts to address noise/land use issues.

## 57

Vincent, Mary, and Darrell Nolton. 1986. Fort Knox ICUZ Program: In Progress Review. Project Report prepared for the U.S. Army Training and Doctrine Command. Fort Belvoir, VA: U.S. Army Corps of Engineers, Institute for Water Resources.

This report evaluates the application of the Installation Compatible Use Zone Community Involvement (ICUZ-CI) process at Fort Knox, Kentucky. The intent is to provide an aid to the U.S. Army Training and Doctrine Command (TRADOC) in assessing its chosen approach to the ICUZ process. The Fort Knox study represents the initial application of the TRADOC ICUZ process. The evaluation is based on a set of interviews with both installation personnel and community leaders involved.

There are four basic action objectives identified for the ICUZ program.

- (1) Achieve future compatible land uses in surrounding communities
- (2) Create a positive public image for the installation
- (3) Reduce noise conflicts
- (4) Implement an installation policy for evaluating noise creation

A fifth objective, designed to facilitate the achievement of the previous four, is to create an open, visible, and traceable process of information exchange.

The analysis of the ICUZ-CI process at Fort Knox identifies a set of lessons which may have application to other installations:

- (1) Prior to undertaking the study, it is necessary to have accurate noise data, command support and interest, and an understanding of the study process.
- (2) After initiating the study, it is necessary to assemble a competent multi-disciplinary team with an active core group and establish study group goals, responsibilities, and a schedule.
- (3) Throughout the process, it is important to maintain effective communications, both within the installation and with the communities involved.

Perhaps the most significant achievement of the ICUZ program at Fort Knox was the development of an effective mechanism for interaction between the installation and the local communities. There is evidence that both sides took action to reduce existent or potential noise problems. The installation reduced conversion plans, from 105 mm to 120 mm guns, by 90 percent. Community leaders and planning departments began to acquire installation input for planning and zoning decisions. An example of a draft Memorandum of Agreement (MOA) proposed to secure future cooperation between the installation and individual local communities is included at the end of the report.

This in-progress review should not be taken as a definitive statement of either the success or failure of the ICUZ program at Fort Knox. Many issues remain unresolved, such as the future value of the MOA. However, some valuable insights into the ICUZ process are provided. Of particular interest is the chronology of events that is included.

## 58

Vos, Joos, and Frank W. M. Geurtsen. 1987.  $L_{eq}$  as a Measure of Annoyance Caused by Gunfire Consisting of Impulses with Various Proportions of Higher and Lower Sound Levels. Journal of Acoustical Society of America 82(4):1201-6.

This article evaluates the adequacy of  $L_{eq}$  as a description of annoyance of impulse noise caused by nine gunfire sounds.

The study design involved a laboratory experiment in which two groups of eight subjects compared the annoyance caused by impulse sounds (G) with the annoyance of road-traffic sounds (T). Nine different impulse sound conditions were presented to each group. One condition involved impulse noise levels at the same level as the traffic noise, while the other eight differed by 6 to 12 dB. One group was allowed to adjust the level of T in such a way so that it was at the same level of annoyance as the standard G, and the other adjusted the G level to the standard G.

Bias penalties for the adjusted  $L_{eq}$  of the variable comparison sounds at which the sounds were judged to be just as annoying as the standard sound were derived for both T and G adjustment groups. The bias penalties were subjected to an analysis of variance (ANOVA) with adjusted sounds as the between-group variable and sound type as the within-group variable. A significant interaction ( $p = 0.01$ ) between adjusted (T or G) and the type of G sound was found, thus implying different results between the two groups.

The results obtained from the subjects who adjusted the T sounds suggest that A-weighted  $L_{eq}$  is an adequate descriptor of annoyance. From the group who adjusted the G sounds, annoyance was lower in conditions in which only a small proportion of the impulses were 12 dB higher than the remaining impulses. This suggests that  $L_{eq}$  may overestimate the annoyance of impulse noise in at least some conditions. Therefore, the authors mildly support the effectiveness of  $L_{eq}$  when annoyance due to impulse sound has to be predicted.

This article provides a useful analysis of the use of  $L_{eq}$  as a measure for impulse sound but stops short of fully endorsing or criticizing  $L_{eq}$  as the correct measure.

## 59

Warnaka, Glenn E. 1987. Applications for Active Noise Control. In Proceedings of Noise-Con 87. Pp. 399-402. New York, NY: Noise Control Foundation.

The author provides a brief description of active noise control and identifies some specific applications now under development.

Active noise control is defined as:

a technique by which transducers produce an out-of-phase signal which mixes with an unwanted noise resulting in destructive interference, or cancellation of both signals.

The phase and amplitude of both waves must be closely matched in order to achieve a high degree of attenuation (e.g. 20 dB). The cancellation wave must be 180 degrees out-of-phase with the signal wave.

Technological improvements are opening up avenues for the application of active noise control in areas such as jet and turbomachinery noise, helicopter rotor noise, exhaust and intake noise, fan and blower noise, spacecraft noise, and underwater noise.

This paper presents a useful introduction to possible future applications of this emergent technology.

## 60

Werlich, M. W., and R. P. Krinsky. 1981. The Aviation Noise Abatement Controversy: Magnificent Laws, Noisy Machines and the Legal Liability Shuffle. Loyola of Los Angeles Law Review. 15:69-102.

This article examines legislation and applicable judicial decision impacting aviation noise abatement activities in the U.S.

The authors present a brief discussion of each of the federal laws and Federal Aviation Administration (FAA) regulations which pertain to aviation noise abatement. The Federal Aviation Act of 1958 authorized the FAA to promulgate Federal Aviation Regulations (FAR's) in part to promote air safety, regulate the use of the navigable air space, and to operate a national system of air traffic control. The exclusive control of airspace was designated as a federal responsibility.



The Federal Aviation Act Amendments of 1968 was the first federal law to recognize the aircraft noise problem. This act authorized the FAA to prescribe standards for the control of aircraft noise emissions. Significantly, the act directed control of aircraft noise as opposed to airport noise and consequently regulations were directed at the source of the noise rather than the airports themselves. The FAA's response to the amendments was FAR Part 36. It specified maximum allowable noise levels that aircraft of new design could not exceed in order to obtain type certification. Since 1969, FAR Part 36 has been amended several times to expand its coverage to all jet-powered and propeller-driven aircraft.

The Noise Control Act of 1972 brought the EPA onto the noise emission regulation scene. The act called for the EPA to develop noise control methods, set noise standards and to coordinate and supervise the noise control programs of other federal agencies. In 1976, the FAA issued its interpretation of congressional intent in the area of aviation noise abatement when it published its Aviation Noise Abatement Policy. In the FAA's view, single liability for noise damages resides with the airport proprietor, but shared responsibility for noise abatement resides jointly among federal, state, and local governments. The question of single versus shared liability is dealt with extensively in the case analysis portion of the article.

The Quiet Communities Act of 1978, the Aviation Safety and Noise Abatement Act of 1979, and the Airport and Airways Development Act of 1970 are also discussed in the context of protecting residents who are located near airports.

The three Supreme Court cases which have been decided on airport noise damages are discussed. These cases are *U.S. v. Causby*, *Griggs v. Allegheny County*, and *City of Burbank v. Lockheed Air Terminal*. The *Causby* decision accepted the plaintiffs claim that frequent, low altitude flights by military aircraft constituted a sufficient interference with the enjoyment of the land has to be considered a taking by the government without compensation. The *Griggs* decision extended the concept used in *Causby* to local airport proprietors. The Court held that the airport proprietor was responsible for acquiring sufficient land adjacent to the airport to reduce the impact of aviation noise and, if it failed to do so, was liable for the resulting damage. The third decision preempted non-proprietor municipalities from imposing aircraft use restrictions on airports in or near their city limits. In *Burbank*, the Court held that an ordinance establishing a curfew on jet aircraft operations at the privately owned Hollywood-Burbank Airport was not within the police powers of the city of Burbank. Importantly, this decision did not consider the limits that may be applied to a municipality which is the proprietor of the airport.

This article is very informative and gives an excellent background on aviation noise regulation and case law.